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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XX.—*On the Distribution and the Secular Variation of Terrestrial Magnetism, No. II;** by L. A. BAUER, PH.D.

IN the present communication it is the intention to endeavor to *localize* the chief cause of asymmetry or distortion in the earth's magnetic field. In a subsequent paper a similar attempt will be made with respect to the secular variation.

How shall we formulate our problem? We do not as yet know conclusively *whether the earth is a magnet or an electro-magnet*—i. e., whether the earth acts upon a freely suspended magnetic needle as a permanently magnetized body, with definite magnetic poles or centers of attraction, or whether it acts like a soft piece of iron rendered temporarily magnetic by a current of electricity circulating around it. To put the matter tersely, no satisfactory answer has as yet been given to the question: "*Is the earth's magnetism permanent or induced?*"

A priori one might be led to the latter opinion. For if we recall that the intensity of the magnetization of the earth can be easily compared with that which we produce with great difficulty in steel magnets and consider the force necessary to increase the magnetization or diminish it, it would seem that the mighty disturbances, termed magnetic storms, which at times simultaneously affect the whole geomagnetic field, would not so readily result if the greater part of the earth's field were in a permanent state. We must have apparently a more sensitive field—one readily susceptible to change.

Peter Barlow in reviewing Biot's, Kraft's and his own researches in 1831 arrived at the following conclusions:—†

* See foot note to No. I in August number of this Journal, Art. XII., p. 109.

† Phil. Trans. Roy. Soc., 1831, Art. VI., p. 102.

a. "That the laws of terrestrial magnetism are inconsistent with those which belong to a permanent magnetic body."

b. "That they are perfectly coincident with those which appertain to a body in the transient state of magnetic induction."

He based these conclusions chiefly upon these facts: Biot (1804) and Kraft (1809) found that by taking a variable distance between the earth's magnetic poles or centers of attraction, supposing them situated on a line through the earth's center at right angles to the magnetic equator, considered as a circle, the accord between observed and computed dip became the more perfect the closer the two poles were made to fall together with the center of the earth. By supposing the centers of magnetic attraction to be coincident with the earth's center, this law was found:

$$\tan I = 2 \tan \varphi \qquad (1)$$

I being the inclination and φ the *magnetic* latitude.

Barlow obtained this identical law both empirically and theoretically when considering the deflections in an inclination needle caused by a soft iron sphere inductively magnetized.* He hence concluded that the earth acts like an inductively magnetized body.

It will be recalled that formula (1) is identical with the law governing the mean inclinations along parallels of latitude as given in conclusion II of the preceding paper.† In the succeeding it will be shown that the same law is obtained on the assumption that the earth is a *permanent uniformly* magnetized sphere. Barlow's deduction does not then necessarily follow.

But let us assume that the earth's field *is* for the greater part an induced one. The next question that might fairly be asked is: *What induces the earth's magnetism?*

Helmholtz characterized the earth's magnetism as one of the most puzzling of natural forces. A volume of very respectable dimensions could be written upon the many theories that have been advanced to account for the origin of telluric magnetism. It seems questionable to me, however, whether this problem as to the *origin* can ever be solved, owing to our inability to form an adequate conception of the earth's condition anterior to all observation. That theory, however, that will explain to us those phenomena that impress themselves forcibly upon us at present, viz., the variations, periodical and non-periodical, will probably be the basis of the one ultimately accepted. In a word, we must investigate the *variations* of geomagnetism and endeavor first to account for them before

* See his "Essay on Magnetic Attractions," 1st ed., 1820, 2nd ed., 1823.

† See this Journal, August, 1895, Art. XII.

attempting the unraveling of the greatest secret of all—the origin of the so-called permanent magnetism.

Thus many plausible theories advanced by eminent and careful philosophers have been shown to be inadequate. Very frequently electrical hypotheses have been proven false by reason of the fact that the theoretical induced currents would not proceed in the requisite direction. As Ampère first pointed out, the observed approximately northward direction of the magnetic needle necessitates electric currents (if they be the cause of the needle's polarity) flowing in an east-west direction. As yet no satisfactory theory has been advanced to account for such induced east-west currents. The thermo-electric hypothesis met with considerable favor at one time and was adopted by eminent geomagneticians. It has, however, been discarded by prominent physicists.

If we have induced currents, then it would appear that according to Gauss's Potential Theory of Terrestrial Magnetism, we must look for them in the earth's crust, not in the atmosphere. It will be recalled that his beautiful investigations proved:

First, that by far the greater portion of the earth's magnetic force possesses a potential.

Second, that the seat of the so-called permanent magnetic force is *within* the surface.

It is a well-known fact that we have earth currents, directed roughly N.E. to S.W., which experience fluctuations concomitant, or nearly so, with a freely suspended magnetic needle. A number of investigators believe themselves to have shown conclusively that these earth currents are *not* sufficient to produce the observed phenomena of the earth's magnetism. This is a matter of difficult experimental determination. A fact clearly indicated, however, is *that earth (and atmospheric) current observations should be more carefully and more frequently made than hitherto and that they should form as much a part of the regular work of a magnetic observatory as the observations of the deflections of a magnetized needle.*

Enough has been given in the preceding remarks to show how infinitely complex and well-nigh hopeless is the solution of the question as to the *origin* of the earth's magnetic field. It is not any more necessary, however, for us to answer this puzzling enigma in order to make headway in the study of terrestrial magnetism, than it is for the astronomer to know, for example, the origin of the moon. He knows the moon exists, and so he determines its disturbing influences upon the earth's motions.

Just so is it with geomagnetism. We do not know the whence but we know its existence. Let us then accept it as part

and parcel of our earth and endeavor to find out the function it plays in the economy of nature's household.

To-day the magnetic earth is rotating about an eccentric axis.* *What has caused this eccentricity?* The relevancy and importance of this interesting question can best be seen from the following extract taken from Prof. Rees's paper on "Variation of Latitude."†

"In an address made before Section A, of the British Association, in 1892, Professor Schuster stated that he believed the evidence at hand was in favor of the view that there was sufficient matter in interplanetary space to make it a conductor of electricity. This conductivity, however, must be small, for if it were not, he said, the earth would gradually set itself to revolve about its magnetic poles. *However, changes in the position of the magnetic poles would tend to prevent this result.*‡ Perhaps the investigator in the near future, working on the suggestion of Prof. Schuster, may find some connection between the earth's magnetism, rotation-time and position of rotation-axis."

Let us assume that the earth's field was originally uniform and symmetrical about the geographical axis. The magnetic poles (whether defined as the points of vertical dip or of maximum or minimum potential) fall together with the rotation poles. At every point on the earth the compass points truly north and south. In every parallel of latitude, the potential, the intensity, and the inclination are constant, though varying according to definite laws from parallel to parallel. The line of zero equipotential, the line of no dip and the line of maximum horizontal intensity fall together with the geographical equator. Let some cause operate now to deflect the magnetic axis or to tilt the primary uniform field until at some given date the magnetic axis is observed to make a definite angle with the rotation axis. We will suppose, for the present, that the field is still uniform about the new magnetic axis. If we were now to determine the difference of inclination, for example, at various points along a parallel of latitude caused by the change in the magnetic axis, and imagine perpendiculars erected at the points of observation proportional to the observed inclination differences, having due regard to sign, then would the surface passing through the ends of the perpendicu-

* The term "magnetic axis" is used throughout in the Gaussian sense, i. e., that straight line with reference to which the earth's magnetic moment is a maximum. This is the only precise definition that can be given this term in the case of such a heterogeneously magnetized body as the earth. According to the latest computation (Neumayer-Petersen's), the magnetic axis makes an angle of 11°·7 with the geographical axis.

† "Science," May 24, 1895, pp. 563-564.

‡ The italics are my own.

lars give us a clue as to the location of the operating cause. Sometimes the secondary inclination would be greater, sometimes less than the primary. Some of the differences would be plus and some minus. Hence, on certain parts of the earth's surface the perpendiculars will point *above* the surface, at others *below*. The result will be that the enveloping surface will lie partly above the earth, partly below. The difference between this surface and the earth's will everywhere give us a measure of the deflecting forces, the maximum departure of the surfaces occurring over the seat of the forces. The curve of intersection of the surface with the earth will pass through all the points on the earth where the deflecting forces have neutralized each other and where in consequence, the particular element, under consideration, has suffered no change.

This is precisely the method we would adopt in making a thermic survey of a region in order to locate the cause of disturbance in a uniform heat distribution. We observe the temperature at various points, imagine perpendiculars erected, lay off on them proportionately the temperature observed and imagine a surface passing through the ends. The seat of heat disturbance would then be indicated on this model by a hillock or peak.

Instead of considering one element alone it would be preferable to include all three at the same time, viz: declination, inclination and intensity, and combine them into vector quantities. These latter could in turn be broken up into three rectangular components, or if the earth's magnetic force possesses a potential, as in fact the greater part seems to do, be treated as functions of a potential. For my purposes, however, it seems preferable to consider the observed elements separately, but simultaneously, and to begin with the dip. The special reason why this path appears better is that I shall have to carry out the idea referred to in the foregoing for various dates, some of them anterior to intensity observations. When considering the secular shift of the disturbing forces, we are, namely, restricted to angular quantities, declination and inclination. In order then to have all my results strictly comparable, I shall have to deal almost entirely with these two elements.

On the supposition that the earth is uniformly magnetized about the geographical axis, we shall get the following value of the potential at any external point P if the X axis of a rectangular system of coördinates is taken coincident with the magnetic or geographical axis, and the origin at the earth's center:*

* See Encyclopædia Britannica, Article Magnetism, p. 232, eq. xxx.

$$(1) \qquad \Psi = \tfrac{4}{3}\pi\mu a^3 . \frac{x}{r^3}$$

a, is the mean radius of the earth, r the distance of P from the origin, and μ the intensity of magnetization per unit of volume. For points on the earth's surface (1) reduces to

$$(2) \qquad \Psi = \tfrac{4}{3}\pi\mu a . \cos u = c . a \sin \varphi$$

u being the geographical polar distance, $\varphi = 90° - u$, or the geographical latitude and $c = \frac{4}{3}\pi\mu$, a constant for any particular time and perhaps for all historic times.* Since for the case supposed the horizontal component, H, of magnetic intensity is directed tangentially along the meridian, we obtain by partially differentiating Ψ according to the variable $u' = a . u = a (90° - \varphi)$:

$$(3) \qquad H = -\frac{\partial \Psi}{\partial u'} = \frac{\partial \Psi}{a \partial \varphi} = c . \cos \varphi$$

And for the vertical component, V, directed radially:

$$V = -\frac{\partial \Psi}{\partial r} = -\frac{\partial}{\partial r}\left(\tfrac{4}{3}\pi\mu a^3 . \frac{r \cos u}{r^3}\right) = 2c . a^3 \sin \varphi . \frac{1}{r^3}$$

Putting $r = a$, we get:

$$(4) \qquad V = 2c . \sin \varphi$$

$$(5) \qquad \text{Total force, } F = \sqrt{H^2 + V^2} = c . \sqrt{1 + 3 \sin^2 \varphi}$$

If I be the inclination, then is

$$(6) \qquad \tan I = \frac{V}{H} = 2 \tan \varphi$$

Furthermore for all points on the earth the declination D:

$$(7) \qquad D = 0$$

Formulæ (3), (5) and (6) will be recognized by every nautical geomagnetician. They were deduced empirically, theoretically (in a different way than above) and practically applied to the determination of the compass deviation due to iron on board

* Prof. W. von Bezold in an admirable paper entitled "Uber Isanomalen des erdmagnetischen Potentials," Sitzungsberichte d. Kgl. Preuss. Akad. d. Wiss. zu Berlin, Phys. Math. Classe, April 4, 1895, has deduced the expression

$$\frac{\Psi}{a} = c . \sin \phi$$

empirically with the aid of the mean values of the potential along geographical parallels of latitude. The value of his empirical coefficient was found to be 0·330 for the date 1880. He regarded this empirical formula as one of the most important contributions of his paper.

ship, by Peter Barlow.* By turning back it will be seen that (6) is identical with Biot's and Kraft's formula which these investigators found empirically when considering the magnetic action of the earth. In obtaining (6) the only assumption made was that the earth was *uniformly* magnetized about the geographical axis. Barlow's argument, based on equation (6), that the earth is *inductively* magnetized is, consequently, not necessarily true.†

From (1) it will be seen that if we substitute for $\frac{4}{3}\pi\mu a^3$, M, the magnetic moment of the earth, the external action of the uniform magnetized sphere is identical with that produced by an infinitely small magnet having the same magnetic moment, and situated at the center of the earth. This explains Biot's and Kraft's result that the computed dip became the more perfect the nearer the magnetic poles were moved to the center of the earth.

Inside the sphere the potential will reduce to

$$\Psi' = \tfrac{4}{3}\pi\mu . x \qquad (8)$$

from which it appears that the force $-\frac{\partial \Psi'}{\partial x} = \frac{4}{3}\pi\mu$ is everywhere constant in direction and intensity, i. e. inside the sphere the field is uniform.

Now let us see how closely the above theoretical results will give us the mean values of the various elements along geographical parallels of latitude. To obtain the computed values below I have adopted provisionally for the value of c von Bezold's empirical coëfficient, viz: 0·330. The observed values are the means of equidistant scalings of magnetic charts along parallels of latitude. The values for D and I have been taken from Table I of my former paper (No. I). Those for Ψ, H, V and F have been borrowed from General A. von Tillo.‡

* See his "Essay on Magnetic Attractions."

† This formula (6) is very significant. It tells us that the inclination is independent of c, or the intensity of magnetization. Hence changes in c will not affect I as long as the axis of magnetization coincides with the geographical axis. Any change in I will have to be referred to a change in direction of magnetic axis. Compare Table I of No. I of these contributions (August number) and see how nearly the mean inclination for a geographical parallel has remained constant for a century. It will be doubly interesting now to determine definitely whether the slight fluctuation exhibited is real and not to be described to inaccuracy of chart data.

‡ Comptes Rendus No. 15 (Oct. 8, 1894): Magnétisme moyen du globe et isanomales du magnétisme terrestre. Note by M. Alexis de Tillo.

Lat.	D Obs'd	D Comp'd	I Obs'd	I Comp'd	Ψ/a Obs'd	Ψ/a Comp'd	H Obs'd	H Comp'd	V Obs'd	V Comp'd	F Obs'd	F Comp'd
					C. G. S.		C. G. S.		C. G. S.		C. G. S.	
60° N	+2°·6	0°·0	+75°·2	+73°·9	+0·285	+0·285	+0·14	+0·165	+0·55	+0·572	+0·56	+0·594
40	+0·9	0·0	+59·6	+59·2	+0·21	+0·212	+0·24	+0·253	+0·43	+0·424	0·50	0·495
20	+0·3	0·0	+34·4	+36·1	+0·11	+0·113	+0·32	+0·310	+0·23	+0·226	0·41	0·383
0	+0·7	0·0	− 2·3	0·0	0·00	0·000	+0·34	+0·330	−0·02	0·000	0·35	0·330
20	+1·6	0·0	−36·0	−36·1	−0·11	−0·113	+0·30	+0·310	−0·23	−0·226	0·39	0·383
40	+3·2	0·0	−57·6	−59·2	−0·20	−0·212	+0·24	+0·253	−0·40	−0·424	0·47	0·495
60 S	+2·8	0·0	−70·6	−73·9	−0·275	−0·285	+0·18	+0·165	−0·53	−0·572	0·57	0·594
Mean	+1·7	0·0	+ 0·4	0·0	+0·004	0·000	+0·251	+0·255	+0·004	0·000	+0·464	+0·468

It will be seen that the accord is very good throughout. This is all the more remarkable when we consider the great changes encountered in the values of the magnetic elements in going along a parallel of latitude; as, for example, along 60° North, the inclination suffers a total change of 82°·5 and the declination along the equator a total change of 50°·7! Notwithstanding these great changes, the mean or normal elements correspond very closely to those obtained on the assumption that the earth is uniformly magnetized about the rotation axis. Why is this? Why should the "anomalies" in the distribution so nearly cancel each other in going along a geographical latitude? This is certainly not a result we should expect *a priori* if the asymmetrical distribution of land and water be the cause of the present distribution of telluric magnetism.

We now see the theoretical significance of von Bezold's empirical formula governing the mean value of the potential from latitude to latitude, likewise, that of the empirical deduction, $\tan I = 2 \tan \varphi$ given in conclusion II of preceding paper.

What does the empirical factor, 0·330 imply? According to equation (2) we have:

$$c = 0{\cdot}330 = \tfrac{4}{3}\,\pi\mu$$

If M is the magnetic moment of the earth, then is

$$M = \tfrac{4}{3}\pi a^3 . \mu = c . a^3$$

i. e. volume of sphere times the intensity of magnetization per unit of volume. With value of $c = 0{\cdot}330$ we then get a value of $M = 0{\cdot}330\, a^3$ or $8{\cdot}52 \times 10^{25}$ (C. G. S. units) against $8{\cdot}55 \times 10^{25}$ as determined by Gauss.* Hence we have the theoretical interpretation of this factor.

Furthermore, if we know the mean value of H along a parallel we can rapidly determine with the aid of equation (3) a fair value of the earth's magnetic moment, without making use of the laborious Gaussian computation. To illustrate:

* Gordon's "Physical Treatise on Electricity and Magnetism," 2d ed., vol. I, p. 155.

Latitude.	Date, 1885. Mean H.	M.
40° N.	0·245	0·320 a^3
20	0·327	·348
0	0·341	·341
20	0·292	·311
40 S.	0·232	·303
	Mean	0·325 a^3

The Neumayer-Petersen re-computation of the Gaussian coefficients gave a value for M of 0·322 a^3. Our value then is in fair accord. H was obtained from 18 equidistant scalings of Neumayer's isodynamic chart for 1885.

Is *c or M subject to a secular change?* Below are the values* of M obtained thus far with the aid of the Gaussian theory:

Year.	Computer.	M.
1829	Erman-Petersen	0·327 a^3
1830	Gauss	0·331
1880	Icilius	0·340
1885	Neumayer-Petersen	0·322
	Mean	0·330 a^3

These figures do not tell anything conclusive as yet. We shall consequently for the present assume that the magnetic moment of the earth does not suffer a secular change and adopt as our coëfficient in above theoretical formulæ the value 0·330.

We are now ready to take up the chief object of this paper —the localization of the causes of the present distribution of geomagnetism. I will *assume* that if these causes were *not* operating the value obtained from the foregoing formulæ would be the actually observed values. I shall consider in this paper, the distribution in *the dip* for the year 1885, scaling the inclination from Neumayer's isoclinic chart at every 20° of longitude along parallels ±60°, ±40°, ±20°, ±10° and 0°. For this purpose I determine the departures of the inclinations thus found from those derived by formula (6) and imagine the ideal surface referred to above constructed with the aid of these departures. To give a representation of this surface, the topographer's method of mapping a hilly country by means of contour lines could be adopted. That is, the curves of intersection of equidistant geo-concentric spherical surfaces with the ideal surface could be drawn. The crowding together of these lines would indicate the position of the highest and lowest points of the surface or the seat of the disturbing forces.

* G. Neumayer, "Atlas des Erdmagnetismus," p. 19, Gotha, 1891.

What we actually do, however, is simply to draw lines through all the places on the earth's surface having the same departure from the normal or computed dip. Such lines, I call lines of equal-departing inclination or briefly, "isapoclinics."* On the diagram opposite they have been drawn for the year 1885.

The sign of the differences, ι, is determined in accordance with the formula:

$$\iota = \text{I obs'd} - \text{I comp'd}$$

regarding dip of north end of needle *below* the horizon as positive, above as negative. A plus ι means then that the dip of the north end of the needle has been *increased* by the disturbing force, or the *north* end of the needle has been attracted; a minus ι signifying, that dip of north end has been *diminished*, or the *south* end attracted.

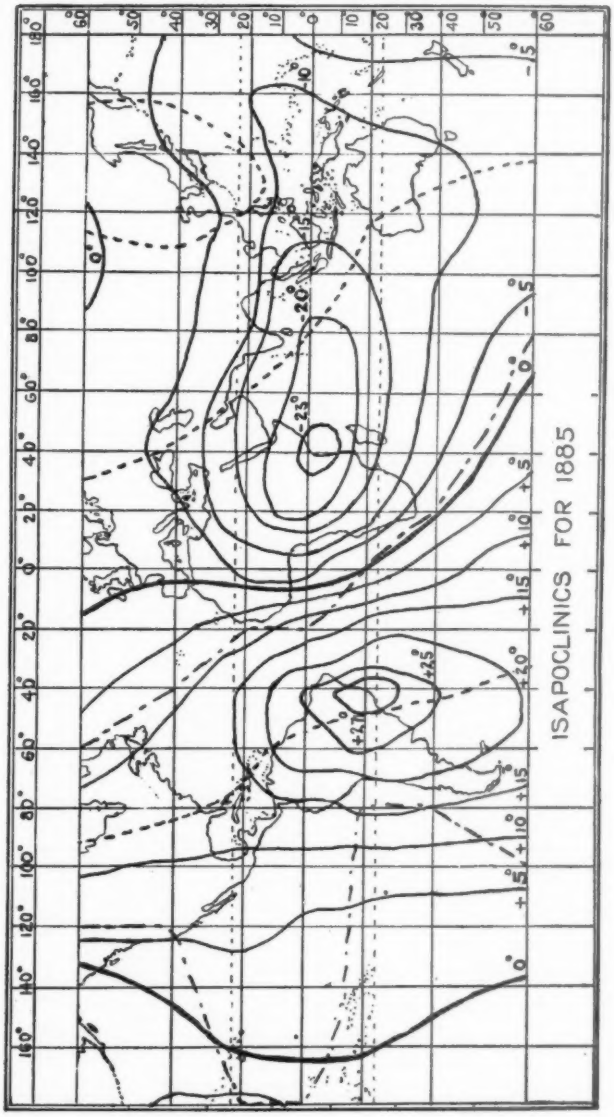
The two heavy lines marked zero, which are but branches of the same closed curve, mark out all those places where $\iota = 0$, or where the dip has the value assuming the earth to be uniformly magnetized about the rotation axis. The region between them on the left has everywhere plus departures, i. e. over this part of the earth the deflecting force attracts the *north* end of the needle. It is seen that these plus isapoclinics encircle a focus, approximately in latitude 20° S. and in longitude 40° W. Here the inclination attains a value of $-7°{\cdot}5$ instead of $-36°{\cdot}1$ prescribed by formula, hence

$$\iota = -7°{\cdot}5 - (-36°{\cdot}1) = +28°{\cdot}6$$

or the north end of the dipping needle is drawn downwards at this point about 29°—this being the maximum plus deflection produced by the disturbing force. *We might regard then this point as the* SEAT *of the force which deflects the north end of the dipping needle from its normal amount, or briefly a secondary north magnetic pole.*

Similarly, the curves of negative departures on the right lead up to a focus in about latitude 5° S. and longitude 40° E. Here the *south* end of the dipping needle is drawn downwards by about 24°. *Hence this focus marks the seat of the south end disturbing force and corresponds thus to a secondary south magnetic pole.*

* The analogous terms for the other elements would be, "isapogonics," "isapodynamics" and "equiabspotentials." These lines are not quite, though nearly, the same as the "isanomalous lines" successfully introduced in terrestrial magnetism by von Bezold and von Tillo which are the equal departing lines, taking the *mean* elements for a parallel of latitude as the normal ones. I have been obliged to adopt the above method for my purposes because: First, it enables me to draw "equal departing lines" without the aid of magnetic charts, since I can *compute* the normal elements for any latitude. This is important when considering the secular variation. Second, it enables me to give precision to the interpretation of the residual or secondary field obtained with the aid of these lines.


ISAPOCLINICS FOR 1885

It will be noticed that the zero isapoclinics, or secondary magnetic equators as they might be termed, lie midway between the secondary magnetic poles.

It is certainly surprising that these two secondary poles which represent the centers of the forces producing the asymmetrical distribution of the earth's magnetism should be on the *same* side of the equator and so nearly on it, instead of on *opposite* sides. Consider now the very asymmetrical distribution of land and water with regard to the equator and it hardly seems possible that this should be the main cause of asymmetry of the earth's magnetic field. In this case one might expect the attracting centers to be either farther north or farther south, as the case may be.

Another remarkable result is the close proximity of these secondary dip poles. They are only 80° apart in longitude. Here we may have an effect due to the heterogeneity in the earth's composition.*

It would appear then that:

The chief cause of distortion of the primary symmetrical field can be represented as due to a secondary polarization approximately equatorial in direction.

The question might fairly be asked what has been gained by assuming that the earth has a primary polar field, uniform and symmetrical, and referring all distortions to a secondary complex field, only approximately equatorial in direction? The answer is, we have placed the disturbing centers where we can *operate* upon them. We have observations of declination and inclination running back in this region for three centuries. It will be investigated in the next number whether we can

* Prof. W. von Bezold in the paper already cited drew the "lines of equal departing potential," or as he terms them "isanomalous lines of geomagnetic potential." He fully develops the theory of these lines and constructs them for 1880, making use of Quintus Icilius's re-computation of the elements of terrestrial magnetism as based upon Gauss's potential theory. He regarded the mean values of the elements along parallels of latitude as the normal ones. He finds that the lines close around two foci, one, the north end attracting, in 26° S. and long. 44° W., the other, the south end attracting, in 49° S. and 140° E. The positions of our secondary north poles agree very well but those of the secondary south poles are very different, though they are roughly in the same region. Just why this is, is difficult to tell at present. The theory of the potential does not prescribe that the vertical dip poles and the foci of maximum or minimum potential should coincide; this depends upon the geometric nature of the equipotential surfaces. Furthermore, my secondary field is derived directly from observation and includes such effects as would not be embraced in the potential theory. Still the prime cause of want of coincidence of our south poles must be referred, doubtless, to the form of the secondary equipotential surfaces. As we proceed in the differentiation of this field, this matter may become clearer. The main fact, however, that the secondary polarization is apparently directed roughly east–west is sufficiently borne out by both investigations. Von Tillo moreover in his paper already cited has found that with respect to all the elements, the isanomolous lines can be referred to an east and to a west hemisphere. It is very much hoped that von Tillo's charts will soon be published.

refer the secular variation to the secular shift of these secondary poles.

I shall now show that these secondary magnetic dip poles are as truly magnetic poles as those which we believe to be in the arctic and antarctic regions. The following main condition must be fulfilled:

In going along a magnetic meridian of the secondary system with a dip needle having its plane in that meridian the north end of the needle must point vertically downwards over the secondary north pole (i. e. over the west focus), at the magnetic equator (the zero isapoclinic), the needle must be horizontal and over the secondary south pole (east focus), the south end must point vertically downwards.

Let us assume for simplicity, that the secondary magnetic dip poles are exactly on the equator, as they are in fact very nearly. The equator will then be a magnetic meridian of the secondary system. The formula for reducing a dip observed in the actual magnetic meridian to the plane passing through the secondary magnetic meridian will be on the assumption made:

$$\tan I_e = \tan I_m \cdot \operatorname{cosec} D$$

I*e* being the dip in the equatorial plane and I*m* the dip in the actual magnetic meridian and D the observed declination. From this it follows that the points where D is zero and I*m* not zero, tan I*e*$=\infty$ or I*e*$= 90°$. In other words, the intersections of the agonic lines with the equator mark the places of vertical dip in the equatorial plane. The dotted lines on the diagram are the agonics. It will be noticed that they pass nearly through the secondary magnetic poles.

The points where the dip needle would be horizontal in the equatorial plane are found with the aid of the above formula, to be in long. 188° E. and 2° W. See how closely these points come to the intersections of the secondary magnetic equator (zero isapoclinics) with the geographical equator.

Since the horizontal component of intensity directed equatorially, H*e*, can be derived from the formula

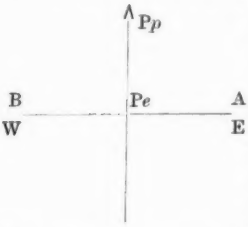
$$H_e = H_m \sin D$$

H*m* being the observed horizontal component in the actual magnetic meridian, it follows that where D is zero H*e* is zero. We have already seen that these points fall in the neighborhood of the secondary poles.*

Again, let us suppose that we have really two magnetic fields instead of one and that they are at right angles to each other, the

* If we construct the isapodynamics with the aid of values of the horizontal intensity scaled from Neumayer's isodynamic chart for 1885, we shall find that the departure of observed intensity from computed intensity is zero for the following two points along the equator, 73° W. and 60° E.

first being the primary polar field, the other the secondary equatorial. Were only the *polar* field present, then would the compass everywhere point due north and south. Were but the *equatorial* field present, the needle would everywhere point east and west. Under the combined action of the *two* fields, the needle takes up an intermediate position. As we proceed along the equator the north end of the compass alternately points E. or W. of N., the points of change from E. to W. or vice versa being over the equatorial poles.



Thus, in the figure, let P*p* represent the north magnetic pole of the polar field, P*e* the same for the equatorial. At A under the combined influence of P*p* and P*e* the north end of the compass points W. of N. As we proceed from A towards P*e*, the westerly declination diminishes until over P*e* it vanishes entirely, the component of horizontal intensity of the secondary field vanishing over P*e*. As we leave P*e* and proceed towards B the needle points E. of N. That is, over the equatorial poles the declination is zero, to the right of the equatorial magnetic north pole, the declination is westerly, to the left, easterly; for the equatorial south magnetic pole, a precisely reverse condition of things obtains.

Hence, if two such systems are present on the earth the actually observed declination ought to be westerly *between* the two isapoclinic foci, and beyond, easterly. Now as a matter of fact over the region *between* the agonics given on the diagram, the declination *is* westerly and beyond them easterly. It will be seen that this region is nearly identical with that prescribed by the foci! In other words, without the knowledge of a single declination observation we might have delineated roughly the region where the declination is westerly or easterly with the aid of the isapoclinics.

It seems to me that the proof is overwhelming that these isapoclinic foci are magnetic dip poles just as truly as the one supposed north of Hudson's Bay. I do not see how we can escape the fact that we have secondary magnetic dip poles situated approximately in the equator. The field that we actually observe is the resultant of the two systems—the polar and the equatorial.

Hence, perhaps the prime reason why a declination needle does not point truly north is because of a secondary polarization approximately equatorial in direction.

To give further proof that the isapoclinics are not random lines but the isoclinics of a definite magnetic system and hence

subject to the laws of such a system, I have drawn on the diagram (p. 199) the lines connecting the places of maximum west and east declination along parallels of latitude. These lines are indicated thus: ——.——. The one on the left connects the places of maximum easterly declination; the other, skirting the west coast of Africa, passes through the places of maximum westerly declination. If the foregoing deduction is true that the secondary system causes the deflection of the declination needle, then since the horizontal intensity component of the secondary system is a maximum along the secondary magnetic equator, the lines of maximum declination should follow somewhat the zero isapoclinies. It will be noticed that this is roughly true. Exact coincidence must not be expected, since the magnetic intensity equator and dip equator do not necessarily fall together on account of the complexity of the secondary system.

Let us compare roughly the maximum horizontal intensities of the two systems. For the total uniform system we obtain the maximum value of 0·330 C. G. S. in the geographical equator (see table, p. 196).

If we resolve the observed horizontal component in the geographical equator into two components, one directed due north (X component) and the other, directed west (Y component) we shall get these values near the secondary magnetic equator:

Long.	X	Y	$\frac{X}{Y}$
40° W.	·293	+·049	6·0
20 W.	·276	+·106	2·6
0	·283	+·097	2·9
20 E.	·293	+·069	4·3
160 E.	·365	−·047	7·8
180	·364	−·056	6·5
160 W.	·357	−·041	8·7
Mean			5·6

Or, the polar field is on the average about 5 or 6 times stronger than the equatorial. *In other words, if the magnetic moment of the resultant system be taken as* $0{\cdot}330\times a^3$, *that of the primary is roughly,* $0{\cdot}325\times a^3$, *and of the secondary* $0{\cdot}060\times a^3$.

In consequence of this secondary magnetic moment attached to the primary, roughly at right angles, the axis of the resultant magnetic system must incline towards the equator by an amount u computed thus:

$$\tan u = \frac{0{\cdot}058 \times a^3}{0{\cdot}325 \times a^3} = \frac{1}{5{\cdot}6} = 0{\cdot}1786$$

$$\text{hence } u = \quad 10°{\cdot}1$$

or the equatorial inclination of the actual magnetic axis would be about 80°. The latest computation based on the Gaussian potential theory gave a value of 78°·3. The close coincidence is certainly striking.

Hence,

The principal phenomena of the distribution of terrestrial magnetism can be regarded as produced by two rectangular magnetic systems, a polar and an equatorial, the former of about 5 or 6 times the strength of the latter.

Since, in going around the earth along a geographical parallel of latitude, the deflections due to the secondary system almost balance each other, as shown by the fact that the mean elements so nearly agree with the computed ones of the primary polar system (see table, p. 196), the inference might be drawn *that the secondary field is in some way connected with the earth's rotation.*

In a subsequent number of these contributions, this matter will be examined in detail from a theoretical standpoint. For this reason, I shall make no attempt in the present paper to resolve the complex secondary magnetic system shown on the diagram into its components. The field as exhibited may really be a resultant one of three—a theoretical equatorial field, a field due to electric currents piercing the earth* and a third, due to the heteorogeneity of the earth's composition.

*Such currents have been made probable by Dr. A. Schmidt's beautiful researches. (See his brief note in Report of the Brit. Ass. for Adv. of Science, for 1894, p. 570.) They may be due to the following reason:

If an arbitrarily magnetized sphere rotates in a conducting fluid, the surface of contact of sphere and fluid being also conducting, currents will be incited in the fluid which pass into the sphere, suffer a deflection and then pass out again. While in the case of the earth, there is perhaps no fluid with respect to which the solid earth performs a *complete* differential rotation, there are *partial* differential rotations, due to moving streams, ocean currents, tidal waves and air currents. In the latter case it is also quite possible to have complete differential rotations if we take into consideration the mighty polar whirls of the primary atmospheric circulation. See also quotation with respect to Professor Schuster's work, p. 192.

Washington City, June 4, 1895.

ART. XXI.—*On Outlying Areas of the Comanche Series in Kansas, Oklahoma and New Mexico;* by R. T. HILL.*

THE Tertiary Plains formations of western Kansas, Texas and eastern New Mexico constitute the summits of extensive levels or plateaus. The eastern border has an average altitude of 2000 feet in Kansas and 2500 feet in Texas.

The Medicine Lodge, Cimarron, Canadian, Red, Brazos, and Colorado rivers originate along the eastern escarpment of the Great Plains and are rapidly destroying them by head-water erosion. These streams are types of the valleys of the rivers of the central denuded region which rise in the eastern margin of the plains, as distinguished from the rivers of the plains such as the Republican and Smoky Hill, which rise and flow upon the plains formations, and from the rivers of the mountains which transect the plains.

The sources of these marginal rivers consist of many digitate branches along the eastern border of the plains. These streams soon cut through the Tertiary formations composing the surface of the plains, down into the underlying red beds of undetermined age, which are the chief components of the underlying floor. These valleys are bordered by mural escarpments of red beds, capped by remnantal patches of the Plains formation between which are preserved occasional patches of the Cretaceous formations.

In proceeding southward the first region of the breaks of the plains with their escarpments of picturesque Red Bed scenery, is the valley of the Medicine Lodge River of Kansas—the so-called "Gypsum Hills" country of many writers.

This region, which lies along the south central border of Kansas in the counties of Harper, Barber, Comanche and Meade, abounds in data throwing light upon the problems of the Pleistocene, Tertiary, Cretaceous and Permo-Trias history. Its geology has been mentioned by earlier writers, especially Professors O. P. St. John† and Robert Hay.‡ The latter has given an interesting and graphic description of the structure and scenery and pointed out the great denudation which preceded the Tertiary sedimentation.

Near the head-waters of this river a thin group of Cretaceous formations lies between the Tertiary and the Red Beds. To the east the Plains formations rest directly upon the Red

* Published by permission of the Director of the United States Geological Survey.

† Notes on the Geology of Southwest Kansas, by O. P. St. John, Fifth Biennial Report, Kansas State Board of Agriculture, Topeka, 1887, Part II, pp. 132, 152.

‡ A Geological Reconnoissance in Southwestern Kansas, by Robt. Hay, Bull. 57, U. S. Geological Survey, 1890.

Beds, the intervening Cretaceous deposits having there been denuded in early Tertiary time.

There has been a diversity of opinion as to the age and affinities of the Cretaceous beds of this region. St. John* referred them with the overlying sandstone to the Dakota, but notes certain dissimilarities of structure and fauna from the Dakota as he had seen it elsewhere.

Prof. Robert Hay† has pointed out their dissimilarity to other outcrops of the Cretaceous, and while judiciously not committing himself, said:

"With reserve, we are inclined to place the stratum called the shell bed in the Fort Benton group. . . . Before giving up the Dakota age of the sandstones (one bed in particular) I will have to re-examine the region."

In a later paper,‡ after reviewing subsequent discoveries he says: "There seems no doubt but that they belong to lower horizons than the Kansas Dakota. There is no reason why the Texas names given to the beds [by Prof. Cragin,] Trinity for the lower sandstone, and Comanche Peak for the upper, should not be permanent."

Prof. Cragin has written more voluminously upon the region and its formation than any other writer, and he it was who first brought out the important fact that a portion of the beds were of pre-Dakota age,§ and belonged to the lower-lying Comanche Series which has its typical development in central Texas.

It is impossible in this short paper to give all the reference to Prof. Cragin's age determination of these beds, but in general he has classified the Cretaceous deposits into three conspicuous divisions: a basal member which he has named the Cheyenne sandstone; a group of intermediate shales which he has until lately called the Neocomian shales, and recently terms the Kiowa shales, and an upper sandstone which he calls the Dakota. He has correlated the Cheyenne sandstone with the Trinity sands of Texas and Arkansas, and the Kiowa shales with the Fredericksburg division, and the Dakota with the Dakota. Furthermore, he has generally spoken of the shales as the "Neocomian shales of Kansas." As a result of this classification, the Dakota sandstone was supposed in Kansas to rest directly on the beds of the Fredericksburg division, without the interposition of the sediments of the Washita subepoch.

* Kansas State Board of Agriculture, Fifth Biennial Report, Part II, pp. 142–144, Topeka, 1887.

† Bull. 57, U. S. Geol. Survey, 1890, pp. 29–30.

‡ Geology and Mineral Resources of Kansas, Topeka, 1893, pp. 12–13.

§ See Bull. Washburn Laboratory of Natural History, vol. i, No. 3, vol. ii, Nos. 9, 10, 11. American Geologist, July, 1894, etc.

The writer naturally felt interested in the extension northward into Kansas of the supposed equivalents of the Comanche series of the Texas region as announced by Prof. Cragin, and in August, 1894, proceeded to the region in company with Mr. C. N. Gould, a promising young local student, and Mr. G. B. Shattuck of the post graduate department of Johns Hopkins University. We made minute studies and sections of the localities in Barber and Comanche counties. The present observations are based upon extensive studies and collections made upon this trip.

Four miles west of Sun City a small remnant of the Cretaceous, hardly 100 feet long, 50 feet broad, and not over 40 feet thick, forms a cap to a Red Bed butte. This is the easternmost Cretaceous formation interpolated between the Red Beds and Tertiary, as seen by the writer on this journey.* This outcrop is the remnantal base of the Cretaceous formations, more fully developed to the westward.

About two miles west, upon the northeast land section of Comanche county, a more extensive and thicker outcrop of the Cretaceous formation occurs. This locality is the "Black Hills" of St. John, Hay and Cragin, so-called from the black color of the shale composing the buttes, as distinguished from the predominant red color of the buttes of the Gypsum Hills region lower down the river. This locality is the easternmost of a continuous series of outcrops exposed from here to west of Belvidere. A minute study was here made of the section, which is as follows, beginning at the bottom:

Section at Black Hills, Northeast Corner of Comanche Co.

	Ft.	Ins.
I. The Red Beds.		
1. Friable beds of finely comminuted sand and clay of intense vermilion color constituting the slopes and base of the butte. Some 400 feet of this formation are exposed. This is the problematical formation known as the Red Beds. Triassic of various writers	300	
II*a*. The Cheyenne Sandstone.		
1. White pack sand, sometimes irregularly cross-bedded, consisting of the loosely or unconsolidated sand known in the Texas region as "pack sand" with occasional fine silicious pebbles. In its upper and exposed portion this sand ultimately becomes ferruginated into light-colored limonitic tints, but sometimes it reveals blotches of vermilion hematitic coloring. The ultimate oxidation, however, is a dark blackish brown. Some kaolinized pebbles were occasionally seen in layers of gravel three inches thick. The total thickness of this formation is	57	

* Prof. Hay notes having seen a patch of these beds in the hills north of Sharon, which are thirty miles east of this locality.

	Ft.	Ins.
2. Blue-black sandy clay shale with limonitic seams. This begins rather abruptly above the sandstone, but its sandy nature indicates that it is a transition and not an unconformity, which is further attested by the occurrence upward in these shales of bands of sand similar and identical in material with the lower sandstone. The shale contains crystals of selenite and dicotyledonous leaf impressions	10	
3. The shale No. 2 in its upper part grades by gradual transition into a bed of sand which superficially indurates into a hard series of layers aggregating four feet in thickness. In these sandstones and shales (No. 2) immediately below it were found the dicotyledons to be mentioned later	4	
IIb. The Belvidere Shales.		
4.* A persistent stratum of small Gryphæate oysters superficially resembling the Comanche Peak variety of *G. pitcheri*. A closer study shows it to be a small form *Gryphæa pitcheri* Morton (*G. dilatata*, var. *tucumcarii* Marcou) imbedded in a sandy shaly matrix not exceeding	1	6
5. A thin white shaly sandstone with plant and molluscan remains		3
6. Thin black sleek paper shale with impressions of mollusca in its lower part	15	6
7. Indurated bed in the shale with occasional minute pebbles	2	
8. Shale like No. 6	4	
9. Sandy induration in shale	2	
10. Shale	5	
11. Indurated shale with Gryphæas	1	
12. Black shale	5	
13. Indurations with var. of *Gryphæa pitcheri* (*G. roemeri* Marcou, *G. forniculata* White), Cyprimeria and Turritella, alternating with shales for a thickness of	20	9
14. Blue shale as above.		
15. Indurated beds with *Exogyra texana* Roemer, Trigonia, sp. Cyprimeria, Turritella and Gryphæas of large size. The upper horizon of 15 containing vertebrates bones, Lingula, etc. Total of Nos. 15 and 16	17	

* Above this oyster bed to the summit of the section, the formation consists mostly of blue papyraceous shales with occasional indurated bands and presenting many fossiliferous horizons, all of which, however, are portions of the same continuous deposition and fauna.

	Ft.	Ins.
16. Fossiliferous shale	16	
17. From No. 16 to the top of the large butte ⅛ mile to the west the thickness of shale is	32	
Making of blue shale with indurated fossil layers a total of	106	

In the shale near the summit of this butte specimens of the large *Gryphæa dilatata* var. *tucumcarii* Marcou, were found.*

As we approach Belvidere the Cheyenne sandstone begins to form the principal slope of the river basin, and west of that village the bed of the river rises until it is upon the Cheyenne sandstones, while some bluffs and castellated remnants of the sandstones are beautifully exposed in the north side of the valley.

Five miles west of Belvidere the railroad has made magnificent cuts into the beds so that they are there seen better than at any other locality. Here the comparatively steep wall of the valley affords a fine section from the old deposition plane of the Great Plains Tertiaries down into the Cheyenne sandstone, the buttes on the south margin of the river valley being remnants of the main body of the plains to the northward. It is here that Prof. Cragin made his Blue Cut mound section,† omitting from it, however, the basal sandstones which are revealed in the floor of the valley near by. Following is the section as measured by Mr. Gould and the writer:

Blue Cut Section.

II. The Cheyenne Sandstone—bottom not exposed.	Ft.	Ins.
1. The Cheyenne sandstones are well shown west of Belvidere in the bluffs on the north side of the river valley, especially in the cliffs of Thompson's Creek. About two and one-half miles west of Belvidere a small creek from the south emptying into the river makes good cuts through the sandstone, showing the same general detail as at Black Hills section.		
2. Sandy shale band above the basal sandstone the same as No. 2 of Black Hills section	8	
3. Thin sandstone layers of the plant beds‡ of Nos. 3 and 4 of the Black Hills section	6	

* See remarks on this species, p. 38.

† Bull. Washburn Laboratory, vol. ii, No. 11, p. 77, 1890.

‡ These beds constitute a low bench immediately adjacent to the river, and the clay shales succeed them, forming the higher outer slope of the valley. I made a general study of the section to the summit; Mr. C. N. Gould made the succeeding accurate measurements and minute collections.

		Ft.	Ins.
II*a*.	Belvidere Shale.		
5.	Black or blue shale	26	
6.	Oyster bed, sandy matrix		2
7.	Black shale	3	6
8.	Oyster bed, in shale		8
9.	Black shale	1	
10.	Oyster bed, in shale		3
11.	Black shale	3	
12.	Oyster bed, in shale		8
13.	Lower part, black shale with much gypsum 3 Upper part quite ferruginous 4	7	
14.	Oyster bed with much gypsum		8
15.	Black shale	5	
16.	Oyster bed weathered	1	
17.	Black shale weathered	3	
18.	Oyster bed, cap on top of cut	2	
19.	From top of cut to top of next Gryphæa bed	20	
20.	To top of next Gryphæa bed	12	
21.	To top of next Gryphæa bed	4	
22.	To top of next Gryphæa bed	12	
	Total,	102	
III.	The "Dakota" Sandstone.		
23.	A small nipple of nearly black ferruginous sandstone, consisting of coarse oölitic-like grains, and containing stems of plants. This is the character of sandstone generally called Dakota in Kansas	20	
IV.	Plains Tertiary:		
24.	White mortar-like rock with calcareous matrix enclosing fine grains of sand	11	

Thirty rods north of the line of the section the Tertiary (No. 24) rests directly on the Belvidere shales, the Dakota (No. 23) having been eroded.

These two sections, taken some miles apart, are sufficient to show the general character of the structure and sedimentation of the beds. They practically agree in thickness and character with the sections of the Belvidere region previously given by Prof. Cragin.*

Reviewing both these sections above the Red Beds (No. 1) and below the Dakota (III), they consist of continuous deposits of shallow marine sedimentation, showing (I*a*) a group of the sand beds at the base (the Cheyenne sandstones of Cragin) grading into an upper portion of thin blue and black shales (II*b*). These shales resemble lithologically the similar blue and black shales of the Meek and Hayden section as seen in the plains and Rocky Mountains of the northwest, and not those of the beds

* Bulletin Washburn Laboratory, vol. ii, No. 11, pp. 75–76, 1890.

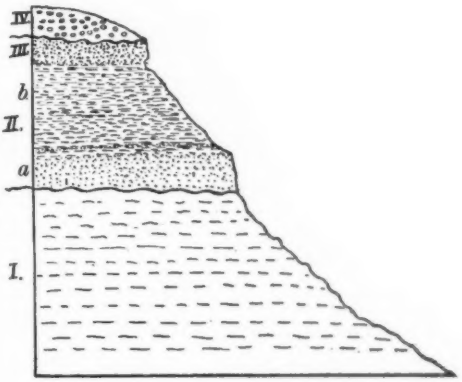
of the Lower Cretaceous of the Central Texas region, which are of a light-colored marly nature.

Although the occurrence of the secondary beds of sandstone, No. 2, 3, and 4, immediately above the main body of that material, is quite persistent both at Black Hills and Blue Cut, Prof. Cragin has not noted its occurrence in his sections of these localities. Whether he failed to observe them, or merely considered them portions of the Cheyenne sandstone to which they logically belong, rather than the shale series above, cannot be stated. That he considered the Cheyenne sandstone and overlying shales a continuous sequence of sedimentation, is clearly shown in his discussion of the Vanheim section, where he finds a band of Cheyenne-like sandstone ten feet thick, intercalated between ninety feet of shale beneath and forty above. The shales overlying No. 4 we call the Belvidere shales from the town near which they can best be seen.*

These formations may be grouped into a generalized section characteristic of the bordering breaks of the Plains in southern Kansas, western Oklahoma, and northeastern New Mexico, which we may appropriately call the Plains section.

This section is as follows:

IV. Plains Tertiary.
III. "Dakota" Sandstone.
II. Belvidere Beds.
b. Blue and black shale with fossils.
a. Cheyenne Sandstone grading upward into *b*.
I. "Red Beds."



In this section there are two conspicuous time unconformities, indicative of long periods of erosion, one between the Red

* Since writing this paper Prof. Cragin has proposed the name Kiowa for the shale beds. The name would no doubt have priority over the one herein used by me, but owing to doubt as to which subdivision Prof. Cragin would have included the beds 2, 3 and 4. I prefer to retain for the present the term Belvidere shales. Although the relations of the Cheyenne sandstones and Belvidere shales are transitional, the writer draws the line of demarcation between the Belvidere shales and the Cheyenne sandstone immediately above this highest sandy layer No. 4, in the sections given.

Beds and the Cretaceous—the other between the Cretaceous and the overlying Tertiary.

Owing to the great erosion which took place between the close of the Cretaceous and the deposition of the plains Tertiary (Miocene and later), any or all of the Cretaceous may be missing in some localities as between the Canadian and Brazos; while south of the head of the Brazos the plains Tertiary rests on the limestones of the Fredericksburg and Trinity divisions of the Comanche series instead of the beds of the Washita division to the northward.

Paleontology: The fossil mollusca was submitted to Mr. T. W. Stanton of the United States Geological Survey, and the fossil plants to Prof. F. H. Knowlton, for determination and study. Their reports are included in the following discussion.

The Cheyenne Sandstone.—Prof. Cragin, as before noted, reported the occurrence of one species of a plant from these beds. This he described as *Cycadoidea munita.** It can be stated that later information concerning the specimens in question, throws doubt as to its occurrence in this identical horizon.

In the lowest sandstone No. 1, only plant stems and small pieces of lignite were found. A well defined flora was found in the sandy shale (No. 2) and the layers (3, 4) immediately overlying the main basal sandstone, and which are genetically related to No. 1, marking the cessation of the initiatory sandy beds of the series; two large boxes of these specimens were collected at Black Hills and submitted to Professor Knowlton, whose appended report speaks for itself. Similar plant remains were observed in the same sand layer near Blue Cut Mound, but night coming on a detailed collection could not be made there.

Report upon a Small Collection of Fossil Plants from Black Hills, near Belvidere, Kansas, collected by Prof. R. T. Hill in August, 1894.

This material has been carefully examined and the following species identified:

Rhus Uddeni Lx.
Sterculia Snowii Lx.
Sassafras Mudgei Lx.
Sassafras cretaceum Newby., var. *obtusum* Lx.
Sassafras, n. sp.
Glyptostrobus gracillinus Lx.
Sequoia sp.

The above species have, according to Lesquereux, the following distribution:

* Bull. Washburn Laboratory, vol. ii, No. 10, p. 65.

Rhus Uddeni Lx.—The locality for this species is simply "Kansas." It is said to have been presented to the U. S. National Museum by the collector, Prof. J. A. Udden, but according to the records it is not now and has never been in this institution. I have lately written to Prof. Udden to find where it came from, and he replies that it is "from the west slope of the Smoky Hill Buttes, near Salemsburg Post Office, Saline county, Kansas."

Sterculia Snowii Lx.—From Ellsworth Co., Kansas, where it is very abundant. It was reported by Mr. W. F. Cummins from the "upper sandstone of the Tucumcari beds, four miles west of Big Tucumcari mountain, New Mexico," and described by him under the name of *Sterculia Drakei.* 3d Ann. Rep. Geol. Survey of Texas, p. 210.

Sassafras Mudgei Lx.—Found on hills along the Salina river, Kansas.

Sassafras cretaceum var. *obtusum* Lx.—Also found on bluffs along the Salina valley, Kansas.

Sassafras n. sp.—This is a small leaf differing from any heretofore described. It, however, approaches to certain well known forms from Kansas.

Glyptostrobus gracillinus Lx.—Found near Sioux City, Iowa, at the mouth of Iowa creek. The collection from near Belvidere contains a number of fairly well preserved examples and there can be no question of its correct identification.

Sequoia? sp.—The collection contains a number of fragmentary cones which appear to belong to this genus. I have not been able to identify them with any known species, and they may be new, although it is hardly safe to found species on such imperfect material.

Indeterminable dicotyledons.—Besides the forms enumerated above, there are a number of fragmentary leaves that it is impossible to determine with satisfaction. They are undoubtedly dicotyledons, but are only fragments with hardly a trace of nervation preserved.

All the above mentioned species belong to the Dakota group as it is usually accepted, but as a matter of fact no detailed stratigraphic work has yet been done with a view to ascertaining the range and association of the fossil plants referred to this formation. It would be natural to suppose that a formation of great thickness and wide areal extent, would have horizons capable of differentiation by means of the fossil plants, but they have not yet been worked out.

If it is shown by stratigraphic and paleontologic data that these leaves come from a horizon lower than that usually recognized as the Dakota group, it would be quite in accord with what should be expected of the Dakota flora. This flora, for years supposed to be the oldest of its type in North America, is made up of a great number of highly differentiated forms, that must have had an anterior period of development. That is, the flora could not have sprung into existence in so abrupt a manner as would seem

to be indicated by previous studies, If more were known of the chronologic sequence of the Dakota flora, it would possibly be found that the plants identified above belonged to lower or older beds. But all that can now be stated is that these species belong to the Dakota group as it has usually been accepted, and have never before been identified outside of it.

Very respectfully,

(Signed) F. H. KNOWLTON,
Ass't Paleontologist.

III. *The Belvidere Shales.*—The fossils enumerated by Prof. Cragin from these shales, especially in his earlier writings, were determined under difficult conditions, remote from large libraries and typical collections, and his synonymy is greatly in need of revision.

From "the Neocomian shales," (the Belvidere shales)—the shales lying between the "Dakota" (No. IV) sandstone at the top and the highest layer of the Cheyenne sandstone, as above defined, Prof. Cragin in his various papers has reported the following fossils.*

Astrocœnia nidiformis Cragin, 7.
(? Nereis incognita Cragin, 6.
Ostrea anomioides Meek, 2.
Ostrea franklini Coquand, 4.
Ostrea diluviana Lam., 2, 4.
Gryphæa bryani Gabb, 2.
Gryphæa pitcheri Morton, 2, 4.
" " var. forniculata White, 4.
Gryphæa vesicularis White, 4.
Exogyra columbella Meek, 2.
" flabellata Goldf, 4.
" forniculata White, 2, 4.
" texana Roemer, 2.
A. argentaria Mort., 4.
Anomia tellinoides Mort., 4.
Plicatula arenaria Meek, 4.
" senescens Cragin, 6.
Neithea quinquecostata Sowerby, 2, 4.
Avicula belviderensis Cragin, 6.
Gervillia sp. allied to G. anceps, 4.
Modiola burlingtonensis Whitfield, 4.
Inoceramus comancheana Cragin, 7.
Inoceramus sp., 3.
Pinna comancheana Cragin, 7.
Cucullæa (Idonearca) terminalis var. recedens Cragin, 6.
Idonearca? tippana Con., 4.
I. vulgaris Con., 4.
Limopsis sp., 4
" subimbricatus Cragin, 6.
Nucula catherina Cragin, 6.
" sp., 4.
Trigonia emoryi Conrad, 2, 3.
Remondia ferrissii Cragin, 4, 6.
Cardita belviderensis Cragin, 6.
Gouldia sp. "Prof. Marcou thinks it an Astarte."

* The figures appended to the names in the list refer to the publications of Prof. Cragin in which they have been used, as follows:

1. Bull. Washburn Laboratory, vol. i, No. 3.
2. Bull. Washburn Laboratory, vol. ii, No. 9.
3. Bull. Washburn Laboratory, vol. ii, No. 10.
4. Bull. Washburn Laboratory, vol. ii, No. 11.
5. Invertebrate Paleontology of the Texas Cretaceous, Austin, June, 1893.
6. Neocomian of Kansas, American Geologist, 1894.
7. Colorado College Studies, 1895.

Cardium belvederi Cragin, 3. (Not described.)
Cardium hillanum Sow. ? 4.
" kansaense, 3.
(?) " mudgeii Cragin.
" (Nemocardium) bisolaris Cragin, 6.
Cyprina ovata M. & H., 2, 3.
Tapes belviderensis Cragin, 6.
Roudaria quadrans Cragin, 4.
Cyprimeria crassa Meek, 2, 4.
" gradata Cragin, 3. (Not described.)
Leptosolen belvederi Cragin, 4. (Not described.)
Leptosolen otterensis Cragin, 6.
Pholadomya? elegans? 4.
" sancta sabæ Roemer, 4.
Homomya alta Roemer, 4.
Liopistha protexta Con., 4.
Mactra antiqua Cragin, 6.
Corbula crassicostata Cragin, 7.
Dentalium, 4.
Trochus texanus Roemer, 6.
Margarita marcouana Cragin, 6.
" (Solariella) Newberryi Cragin, 6.
Neritina sp., 4.
Serpula iintrica White, 2.
Vanikoro propinqua Cragin, 7.
Scalaria sp. (?) 4.
Turritella marnochii White (probably T. seriatim granulata Roemer), 2.
Turritella marnochii White "typical" Cragin, 4.
Turritella marnochii White, var. belvideri Cragin, 4.
Anchura kiowana Cragin, 7.
Globiconcha elevata Shum., 4.
Neritoma marcouana Cragin, 7.
Ammonites acutocarinatus Shum., 3, 4.
A. pedernalis Roemer, 4.
Petersia Medicinensis Cragin, 6.

The large and abundant collections of invertebrate fossils, made by Mr. C. N. Gould and the writer from the shale beds overlying the sandstone from which these fossil plants were collected and grading into them, were determined by Mr. T. W. Stanton, Paleontologist of the U. S. Geological Survey, who reports upon them as follows:

Washington, Jan. 25, 1895.

Mr. R. T. Hill, U. S. Geological Survey.

Dear Sir.—I have the honor to submit the following report on the fossils collected by you last season in southern Kansas.

The collection includes fossils from three different localities, which, according to the labels, are Black Hill, Blue Cut Mound, and hill four miles west of Sun City, Kansas, all of which are in Comanche and Barber counties. The collections from the first two localities are from several different horizons, but as they all evidently belong to one fauna they have all been combined in one annotated list, though the separate lists for each locality and layer are also appended in order that the record may be complete. In connection with the examination I have made a preliminary study of your Washita collection from the Denison section for comparison.

List of Species.

Enallaster sp.—Fragments of an Echinoid referred to this genus by Dr. W. B. Clark. It is not known in beds later than the Comanche series in America.

Ostrea sp.—This species is probably a new form. In size and outline it resembles some specimens of *O. franklini* to which Prof. Cragin referred it, but there are noteworthy differences especially in the beaks and the cartilage pit sufficient for specific separation. This species is very abundant in the shales.

Gryphæa pitcheri Morton.—A few specimens from No. 2 of Blue Cut Mound section seem to belong to this species, though they may be the young of one of the related forms.

Gryphæa forniculata (White).—It is abundant in certain layers. It occurs in the Washita beds at El Paso and the Kiamitia beds of the Washita at Denison and many other places in Texas.

Gryphæa tucumcarii Marcou.—Abundant in the upper part of the section at Blue Cut Mound. It is interesting to note that this form, supposed by Prof. Marcou to be Jurassic, here occurs *above G. forniculata*, which he considered Neocomian, though there is only a few feet difference in the beds and they seem to be connected by intermediate forms. The geographic distribution of the two species is about the same.

Exogyra texana Roemer.—There are only three specimens in the collection. It is abundant at El Paso in beds that are supposed to be Washita and it also occurs at Tucumcari Mountain, New Mexico.

Plicatula senescens Cragin.—Originally described from this region. The material is not sufficient for critical comparison.

Pecten sp.—A small smooth form like one that occurs in the Paw Paw beds of Denison.

Avicula belviderensis Cragin.

Avicula leveretti Cragin ?—Several specimens were collected in the shales of Blue Cut Mound, that agree fairly well with the figure and description of that species from the Kiamitia beds on Duck Creek, Texas.

Inoceramus comancheana Cragin ?—Fragmentary impressions of a form closely related if not identical with this species from the Duck Creek beds.

Lithophagus sp. nov.—Abundant burrowing in *Gryphæa forniculata.*

Nucula catherina Cragin.

Nucula sp.—Casts.

Leda sp.—Casts.

Trigonia emoryi Conrad.—This widely distributed species occurs at Tucumcari, El Paso, etc., and seems to have a great vertical range. It is found in the uppermost Washita beds at Denison and is reported from the Fredericksburg.

Cardita belviderensis Cragin.

Cardium mudgei Cragin?
Cardium bisolaris Cragin.
Cardium (Protocardia) *texanum* Conrad.

Roudaria [?] *quadrans* Cragin.—The Museum contains an example of this species collected by Prof. A. Hyatt at Tucumcari.

Cyprimeria sp.—This abundant species is evidently not *C. crassa*, as Prof. Cragin thought. Our collections of the Texan forms of this genus are not yet large enough for a revision of the species.

Cytherea? sp.—A few casts of an indeterminate Venerid.
Tellina? sp.
Mactra antiqua Cragin.
Corbula crassicostata Cragin, also occurs in the Paw Paw beds.
Dentalium sp.—Represented by fragments.
Natica sp.—A few small casts.

Turritella sp. related to *T. seriatim-granulata* Roemer.—This abundant species does not exactly agree with Roemer's figure nor with any of the four or five other similar species that have been described from Texas. The group needs careful study with large collection from the entire area in order to determine whether we are dealing with several species or only one or two variable forms. The variety now under consideration occurs at Tucumcari.

Anchura kiowana Cragin.—A small form represented by several imperfect specimens. It is closely related to *Anchura mudgei* White, which occurs in the Paw Paw beds, but is apparently not identical with it.

Trochus texanus Roemer.—Two specimens that are doubtless like the one referred to this species by Prof. Cragin. They are somewhat smaller than Roemer's figure, but agree well in sculpture and form.

Schlœnbachia peruviana von Buch.—Two or three characteristic fragments. The species is abundant in the Duck Creek and Kiamitia beds at Denison. It also occurs in the Washita division at El Paso and is said to occur as low as the Walnut clays of the Fredericksburg.

Sphenodiscus sp.—Fragments of a form that differs from *S. pedernalis* von Buch in that it has a truncated periphery. *S. emarginatus* Cragin and *S. rœmeri* Cragin are both related forms from the Fredericksburg and Trinity divisions, respectively, but they do not agree with each other nor with this form in the details of the septa.

A critical examination of the above list will show conclusively that the beds from which the fossils came belong to the Comanche series and probably to the upper half of that series. To make closer correlation with the subdivisions of the Texas section is more difficult because the association of species is not exactly the same as in any one of those subdivisions and some of the species common to the two regions are known to have a considerable vertical range. Taken altogether, the evidence seems to indicate

about the horizon of the Kiamitia. The absence of limestone in the Kansas section adds another element of difficulty in the correlation, because a fauna occurring in shales is often more closely related to a slightly earlier or slightly later fauna in beds of the same lithologic character than it is to a strictly contemporaneous fauna in limestone or sandstone. That is, differences in local faunas are often in part due to differences in depth of water and in character of the sea bottom.

The similarity of the faunas in Kansas, at Tucumcari, New Mexico, and near El Paso, Texas, will allow greater confidence in correlating the beds at these three places.

Very respectfully,
(Signed) T. W. Stanton.

List of Fossils from Black Hills, Kansas.

No. 4. Gryphæa forniculata White. Small specimens—young or depauperate examples of this species.
No. 2, 5 and 9, contain indeterminate fragments of fossils.
No. 6. Corbula crassicostata Cragin.
Ostrea sp.
Gryphæa forniculata White.
Exogyra texana Roemer.
Nucula sp.
Cardium mudgei Cragin?
Cardium bisolaris Cragin.
Roudaria? quadrans Cragin.
Cytherea? sp.
No. 11. Tellina? sp.
Mactra antiqua Cragin.
Corbula crassicostata Cragin.
Dentalium sp.
Natica sp.
Anchura kiowana Cragin.
Trochus texanus Roemer.
Turritella sp. related to T. seriatim-granulata Roem.
Schlœnbachia peruviana von Buch.
Lamna sp.? A shark's tooth probably of this genus.
No. 13. Ostrea sp.
Gryphæa forniculata White.
Cyprimeria sp.
Fragments of other forms occurring in Nos. 11 and 15.
No. 15. Gryphæa forniculata White.
Exogyra texana Roemer.
Avicula belviderensis Cragin.
" leveretti Cragin?
Lithophagus n. sp.
Trigonia emoryi Conrad.
Cardita belviderensis Cragin.
Cardium (Protocardia) texanum Con.
Cyprimeria sp.
Tellina? sp.
Natica sp.
Turritella sp. related to T. seriatim-granulata Roem.
Anchura kiowana Cragin.
Sphenodiscus sp.
Lamna? sp.
Reptilian vertebra.

From Blue Cut Mound, four miles southwest of Belvidere, Kan.

No. 5. Ostrea sp.
Avicula belviderensis Cragin.
Inoceramus sp.
Corbula crassicostata Cragin.
Sphenodiscus sp.
No. 6. Ostrea sp.
Gryphæa pitcheri Morton?
Turritella sp. related to T. seriatim-granulata Roem.

No. 7. Enallaster sp.
Pecten sp.
Avicula.
Nucula catherina Cragin.
Anchura kiowana Cragin.
Sphenodiscus sp.
No. 8. Ostrea sp.
Gryphæa forniculata White.
Plicatula senescens Cragin.
No. 9. Ostrea sp.
Leda sp.
Corbula crassicostata Cragin.
Impressions of several other Pelecypods.
No. 10. Ostrea sp.
No. 11. Cardium mudgei Cragin.
Corbula sp.
Turritella sp. related to T. seriatim-granulata Roem.
No. 12. Ostrea sp.
No. 13. Ostrea sp.
Cytherea? sp.
No. 14. Ostrea sp.
Gryphæa forniculata White.
No. 15. Ostrea sp.
Gryphæa forniculata White.
Corbula crassicostata Cragin.
No. 18. Ostrea sp.
No. 19. Ostrea sp.
Gryphæa tucumcarii Marcou.
Small and rather distorted specimens.
No. 21. Gryphæa tucumcarii Marcou.
No. 22. Gryphæa tucumcarii Marcou.
Cardium mudgei Cragin?
Turritella sp. related to T. seriatim-granulata Roem.
Anchura kiowana Cragin.

List of Fossils from hill four miles west of Sun City.

Cardium mudgei Cragin?
Cyprimeria sp.
Corbula sp.
Turritella sp. related to T. seriatim-granulata Roem.
Anchura kiowana Cragin.

Mr. Stanton reports the following genera and species from the Belvidere shales, at all the localities mentioned:

Enallaster sp.
Ostrea sp.
Gryphæa pitcheri Morton.
G. forniculata White.
Exogyra texana Roemer.
Plicatula senescens Cragin.
Pecten sp.
Avicula belviderensis Cragin.
Avicula leveretti Cragin, Texas.
Inoceramus comancheanaCragin.
Lithophagus sp.
Nucula catherina Cragin.
Nucula sp.
Leda sp.
Trigonia emoryii Conrad.
Cardita belviderensis Cragin.
Cardium bisolaris Cragin.
Cardium (Protocardia) texanum Conrad.
Cyprimeria sp.
Cytherea?
Tellina? sp.
Mactra antiqua Cragin.
Corbula crassicostata Cragin.
Roudaria? quadrans Cragin.
Dentalium sp.
Natica.
Turritella sp. related to T. seriatim-granulata Roemer.
Anchura kiowana Cragin.
Trochus texanus Roemer.
Schlœnbachia peruviana von Buch.
Sphenodiscus sp.

The foregoing studies of the flora and fauna by Professors Knowlton and Stanton, aside from my own opinions, dis-

agree with Prof. Cragin's conclusions on the age and position of the Cheyenne sandstone and Belvidere shales, which he referred to the Neocomian in general and to the Trinity and Fredericksburg divisions of the Comanche series in Texas and Arkansas in particular. It is difficult to find a basis for Prof. Cragin's conclusions in the paleontology testimony he himself has presented, as will now be shown.

An analysis of the species at various times reported by Prof. Cragin, from the Belvidere shales, shows the following well-known species peculiar to the greater divisions of the Cretaceous in other regions of the United States.

Ripley, uppermost Cretaceous of Atlantic coastal region:

Neithea quinquacostata Sow.
Anomia tellinoides Meek.
A. argentaria Morton.
Gryphæa bryani Gabb.
Modiola burlingtonensis Whitfield.
Idonearca tippana Conrad.
I. vulgaris Conrad.
Liopistha protexta Conrad.
Eight species.

Montana division (western equivalent of Ripley of Atlantic coast):

Cyprina ovata M. & H.
Ostrea anomioides Meek.
Two species.

Colorado Group (middle division of Upper Cretaceous):

Ostrea diluviana? Lam. Austin Chalk.
Cyprimeria crassa Benton (probably Montana) New Mexico.
Plicatula arenaria.
Three species.

Dakota Group:

Cardium kansasense Meek, Salina, Kansas.
One species.

Washita division of the main area of the Comanche series:

Gryphæa forniculata White.
Gryphæa pitcheri Mort.
Exogyra flabellata i. e. texana.
Neithea occidentalis Conrad.
Nucula catherina Cragin.
Inoceramus comancheana Cragin.
Trigonia emoryii Conrad.
Cardium hillanum Sow. (i. e. texanum Conrad).
Corbula crassicostata Cragin.
Pholodomya sancti sabæ Roemer
Turritella marnochii White.
A. acutocarinatus Shum., i. e. peruvianus de Buch.
Twelve species.

Species common to Fredericksburg and Washita divisions:

A. peruvianus von Buch.
One species.

Fredericksburg or Middle division Comanche series:

Exogyra texana Roemer.	Trochus texanus Roemer.
	Two species.

Trinity or Basal division:

Homomya alta Roemer.	Ostrea franklini Coquand.
Cucullæa terminalis Conrad.	Three species.

He reports two species which have been found in the Washita of Tucumcari:

Pinna comancheana Cragin.	Cardita belviderensis Cragin.

Besides the above he gives the following species, so far reported to occur only in these beds. (Total 21 species.)

Astrocœnia nidiformis.	Cardium mudgei Cragin.
Nereis incognita Cragin.	Roudaria ? quadrans Cragin.
Plicatula senescens Cragin.	Tapes belviderensis Cragin.
Avicula belviderensis Cragin.	Pholadomya ? elegans ? Cragin.
Petersia medicinensis Cragin.	Mactra antiqua Cragin.
Remondia ferrissii Cragin.	Leptosolen otterensis Cragin.
Limopsis subimbricatus Cragin.	Neritoma marcouana Cragin.
Cucullæa terminalis, var. recedens Cragin.	Vanikora propinqua Cragin.
	Anchura kiowana Cragin.
Cardita belviderensis Cragin	Margarita marcouana Cragin.
Cardium (Nemocardium) bisolaris Cragin.	M. (Solariella) Newberryi Cragin.

From this list we can now strike out two species, *O. franklini* Coquand, which has been disproved by Stanton, and *Cucullæa terminalis* Conrad, abandoned by Cragin.

A similar analysis of the list of species given by Mr. Stanton results as follows:

He finds none of the eight Ripley species reported by Prof. Cragin, nor any of the forms reported from Montana, Colorado, Dakota, or Trinity divisions.

He finds fifteen forms previously identified in the Washita division of the North Texas region, as follows:

Gryphæa tucumcarii Marcou.	Inoceramus comancheana Cragin.
Gryphæa pitcheri Morton.	Trigonia emoryi, Conrad.
Exogyra forniculata White.	Nucula catherina Cragin.
Exogyra texana Roemer.	Corbula crassicostata Cragin.
Avicula leveretti Cragin ?	Trochus texana Roemer.
Cardium (Protocardia) texanum Conrad.	Schlœnbachia peruvianus von Buch.
Cyprimeria sp.	Sphenodiscus sp.
Turritella, related to T. seriatim-granulata Roemer.	Total fifteen.

Common to Washita and Fredericksburg:

Exogyra texana Roemer. Schlœnbachia peruvianus von Buch.

Fredericksburg division:

Trochus texanus Roemer.

Mr. Stanton also finds the following species described from Kansas by Cragin, viz.:

Cardium bisolaris Cragin.	Nucula catherina Cragin.
Mactra antiqua Cragin.	Cardita belviderensis Cragin.
Plicatula senescens Cragin.	Corbula crassicostata Cragin.
Avicula belviderensis Cragin	Inoceramus comancheana Cragin.
Roudaria quadrans Cragin.	Anchura kiowana Cragin.

Total ten.

Tabulating these results, they show:

	Reported by Cragin.	Reported by Stanton.
Uppermost Cretaceous { Ripley species, 8 / Montana, 2 }	10	0
Colorado species	3	0
Dakota species	1	0
Washita species, { Texan, 11 / Tucumcari, 2 }	13	15
Belvidere species	21	10
Common to Washita and Fredericksburg	2	2
Fredericksburg species	1	1
Trinity species	1	0
Species common to other localities, 31		
Peculiar species 21		
Total	52	28

When Prof. Cragin first announced the occurrence of *Ostrea franklini* and the Trinity sands in Kansas—before giving the paleontologic details since published—the writer was inclined to accept his conclusions.* But as Prof. Cragin's paleontologic publications progressed, it became my opinion, even without having seen the region, that the Belvidere beds of Kansas represented the writer's upper or Washita division of the Lower Cretaceous section, and not entirely the Fredericksburg and Trinity as asserted by Cragin. This opinion was confirmed after seeing, later, Prof. Cragin's collections at Washburn College.

If distantly situated beds are to be correlated by the law of common species, it is impossible to see upon what ground Prof. Cragin referred these beds entirely to the Trinity and Fredericks-

* See Annual Report Arkansas Geological Survey, vol. ii, 1888, p. 115.

burg. According to the fauna as identified by him and as analyzed above, they could more logically have been referred to the uppermost Upper Cretaceous (the Montana division) than to the Fredericksburg, since the list contains more Ripley-Montana than Fredericksburg species. But the Washita species as enumerated by him far exceed those from all other divisions, and hence upon his own data the beds should have been chiefly referred to this division.

Concerning the alleged Ripley, Montana, Colorado and Dakota species mentioned by Prof. Cragin, it is strange that none of them were found in the collections studied by Mr. Stanton, and we cannot escape the conclusion that they were founded upon erroneous identifications.

Mr. Stanton's studies of the fossils of the Belvidere shales also demonstrate the opinion I have long entertained, that these fossils are largely of the age of the Washita division of my Texas section, and not solely the Fredericksburg and Trinity divisions, as maintained by Cragin. I am glad to have my own conclusions sustained by such an authority, and I fully agree with him that the Belvidere beds represent in general the Washita division and probably the attenuated Fredericksburg as seen in the North Texas section.

There are several points more strongly suggesting this affinity than Mr. Stanton has brought out. Mr. Stanton's diagnosis removes the alleged *O. franklini* from the list of Kansas species, while Prof. Cragin himself has retracted the other Trinity species (*Cucullæa terminalis* Conrad) which he once reported.* The facts eliminate the sole molluscan species upon which Prof. Cragin could correlate these formations with the Trinity division of Texas.

Mr. Stanton also finds in the Belvidere shales two additional species which Cragin himself has recently described from Texas, to wit: *Avicula leveretti*,† of the Washita of Denton county, Texas, and the peculiar *Inoceramus* to which I have called attention in previous writings, as being found only in the Preston beds,‡ and to which Prof. Cragin has recently given the name *I. comancheana*.§ Thus we have common to the Belvidere beds of Kansas and the Preston beds of the Washita division of Texas and Indian Territory the following peculiar species which occur in no other geologic horizon, and seem to intimately connect these beds at the two localities:

* American Geologist, vol. xiv, 1894, p. 3.

† Invertebrate Paleontology of the Texas Cretaceous, Austin, June, 1893, pp. 171–172.

‡ Bull. Geol. Soc. of America, vol. v, p. 332.

§ Colorado College Studies, 1894, p. 53.

Gryphæa forniculata White.
Avicula leveretti Cragin.
Inoceramus comancheana Cragin.

Of the fifteen recognized species common to both the Kansas and Texas regions all occur in the Washita division of Texas and eleven are found only in it. The Fredericksburg fossils reported by him with the exception of one little known fossil hitherto reported only from the Caprina limestone of the Fredericksburg (*Trochus texana* Roemer), are all of species which in Texas also occur in the Washita division. These species are as follows: *Exogyra texana* Roemer, *Sphenodiscus sp.* Cragin, *Schlœnbachia peruviana* von Buch, and *Trigonia emoryi* Conrad. In all the writer's years of labor and study of the region he has never seen *Trigonia emoryi* in the beds of the Fredericksburg division, and although so reported by the Texas Geological Survey, he does not believe it occurs there, while it is common, abundant and widely distributed in the beds of the Washita division.

The *Sphenodiscus* from the Belvidere beds may possibly be confused with *S. pedernalis* Roemer, of the Fredericksburg division. A large number of undescribed species belonging to this group of Ammonites occur in the Comanche Series from the Glen Rose through the Washita division. The writer has observed these differences for years and submitted the species to eminent authorities. It can only be said now, as Mr. Stanton has already said, that the Sphenodiscus of the Belvidere beds—a figure of which without description has been published by Cragin*—is not *S. pedernalis* of Roemer. On the other hand, some of the Belvidere specimens seem to resemble species occurring in the Denison beds of the Washita division.

This leaves only two undoubted species common to the Fredericksburg and Washita in the Belvidere beds. These are *Exogyra texana* Roemer, and *Schlœnbachia peruvianus* von Buch.

Exogyra texana Roemer is found to range upward into the Washita division in New Mexico, in Trans Pecos, Texas, and at El Paso, but the writer, in the course of his extensive observations, has never seen it in Central Texas above the Fredericksburg division. While this form usually has a well defined zone of abundance in the Walnut clays at the base of the Fredericksburg division, it really has a wide vertical range, occurring in the underlying Glen Rose and the upper beds of the Caprina limestone in the Austin region and associated with a Fort Worth fauna at Frontera, three miles west of El Paso.

* The Neocomian of Kansas, American Geologist, 1894, Plate I, fig. 4.

As has been previously shown by Roemer, this species greatly resembles *Exogyra matheroniana*, an allied species, which in Europe also has a wide vertical range and extends as high as the Senonian. It was largely owing to its abundant occurrence in Texas that Roemer made the cardinal mistake of considering the Lower Cretaceous beds to be Upper.

On the other hand, none of the many peculiarly characteristic Fredericksburg species of Texas occurs in the Kansas beds.

Concerning the twenty-three species which Prof. Cragin describes and which have as yet been reported only from the Belvidere shales, the writer believes that many of them are due to the fact that they represent the naturally denser population of the more northern shallower littorals; others will be found to occur in the rich unstudied littoral faunas of the Washita division in North Texas,* while some of them will be reduced to synonyms. They all belong to that group of littoral genera with a wide range and of little value for minute correlation.

The species called throughout this paper *Gryphæa forniculata* White is the same as the one from Comet Creek, Oklahoma, first figured by Prof. Marcou as *Gryphæa pitcheri* Morton,† and later called by him *Gryphæa Rœmeri*.‡ The nomenclature of the Gryphæata oysters of the Comanche series will be thoroughly revised in a separate paper which the writer has in print. Prof. Marcou's name *G. Rœmeri* probably has precedence over *G. forniculata* White, but it may be shown neither of these will stand.

This Gryphæa so abundant at Belvidere is likewise found in great numbers in the Kiamitia clays, not only about Denison and Fort Worth, but also along a persistent line of 300 miles from Goodland, Indian Territory, to south of the Brazos in Texas. Its hemera in Texas is exclusively confined to the Preston beds, and Prof. Marcou has always held that it is a Cretaceous form; it is the species upon which he established the existence of the alleged Neocomian in America.

An interesting fact in the Black Hills and Blue Cut sections is that the large Gryphæa which comes in near the top of the shales is identical with the form collected by Prof. Marcou and is the species called *Gryphæa tucumcarii* by him (later called *Gryphæa dilatata* var. *tucumcarii*).§

* Since penning these words Prof. Cragin himself has already verified this prophecy by publishing many species from the Denison beds which emphasize this assertion. See Fifth Annual Publication, Colorado College Studies, received April, 1895.

† Geology of North America, Plate IV, fig. 5, 5*a*, 6.

‡ Proc. Boston Soc. Natural History, 1861, p. 95.

§ Loc. cit., Pl. IV, fig. 1, 1*a*, 2.

Prof. Marcou insisted that the beds from which this species came were of Jurassic age, and upon its occurrence he maintained the existence of the Jurassic system in this region. It occurs at Belvidere, as on the original plains of the Kiamitia near Goodland, in Indian Territory, where it was last year collected by Mr. T. Wayland Vaughan of my division, and at Kent* in Trans Pecos, Texas, stratigraphically above and intimately associated with the species which he called *Gryphæa pitcheri*. Thus we have in Kansas and Indian Territory Prof. Marcou's alleged Jurassic species occurring stratigraphically above species he called Cretaceous, which facts forever remove any previous doubt, if any existed, in favor of his theory of the existence of the Jurassic formation in Texas, Indian Territory, New Mexican region.

A lithologic comparison of the Belvidere shales and those of the Washita division, North Texas section, is also of interest. While differing in detail, there is one broad generic resemblance. They are both in general shallower water deposits than the beds of the Fredericksburg division, the shales being blacker and containing beds of littoral sand.

Owing to the underlying Dakota flora of the Cheyenne sandstone there may be doubt in the minds of some whether to assign the Belvidere shale to the Dakota or to the Washita division, but it is difficult in view of the facts presented to see upon what possible ground they could have been referred to the Trinity division.

Prof. Knowlton's determination of the dicotyledonous Dakota flora in the top of the Cheyenne sandstone shows that from a paleontologic standpoint these sandstones have no resemblance to the flora of the Trinity division at Glen Rose, Texas, beds which contains a flora of typical Potomac non-dicotyledonous species.† The Cheyenne sandstones are of far later age than the Trinity, and occupy a stratigraphic position at the base of the Washita midway between the Trinity and the Dakota.

These facts being true, Prof. Cragin's assertion that the Dakota sandstone (No. IV of the general section) in Kansas rests directly on the Fredericksburg division without the intervention of the Washita division is also disproved.

Concerning the correlation of the Belvidere beds with the Neocomian, as done by Prof. Cragin, we can only repeat our opinion, founded upon facts previously given, that the Washita division is homotaxially nearer the equivalent of the Gault, and that the lower lying beds of the Trinity division are

* According to Mr. E. T. Dumble, American Geologist, November, 1893, pp. 310–312.

† See Proceedings U. S. National Museum, vol. xvi, pp. 261–282.

more nearly the nearer equivalents of the Neocomian in the United States.*

The Camp Supply Beds.—There can be little doubt but that the localities of the Cretaceous near Camp Supply reported by Prof. Cope,† and at Comet Creek, reported by Prof. Jules Marcou,‡ represent a portion of the same general sedimentation as the Belvidere beds which Prof. Cragin himself has reported in Northern Oklahoma.

From the beds near Camp Supply Prof. Brown, of the University of Kansas, reports eleven invertebrate species, as follows:

1. Gryphæa§ forniculata White.
2. Exogyra texana Roem.
3. Ostrea‖ subovata Shum.
4. Ostrea quadriplicata Shum. (variety).
5. Cucullæa terminalis Conrad.
6. Neithea occidentalis Conrad.
7. Plicatula incongrua Cragin.
8. Trigonia emoryii Conrad.
9. Trigonia sp.
10. Turritella seriatim granulata Roemer.
11. Schlœnbachia peruvianus von Buch.

Of the nine species named, the following have been reported from the Belvidere shales of Kansas:

1. Exogyra texana Roemer.
2. Gryphæa forniculata White.
3. Trigonia emoryii Conrad.
4. Cucullæa terminalis Conrad.
5. Turritella seriatim granulata Roemer.
6. Schlœnbachia peruvianus von Buch.

The following are characteristic species of the Washita division of Central Texas:

1. Gryphæa forniculata White.
2. Ostrea subovata Shum.¶
3. Ostrea quadriplicata Roemer.
4. Plicatula incongrua Conrad.
5. Trigonia emoryii Conrad.
6. Schlœnbachia peruvianus von Buch.

The following species are common to the Fredericksburg and Washita divisions of Texas:

Neithea occidentalis Conrad.
Turritella seriatim-granulata Roemer.
Schlœnbachia peruvianus von Buch.

* Age and Significance of the Trinity Division. Proc. Biological Society of Washington, vol. viii, pp. 17–20, 1893. Bull. Geol. Soc. of America, vol. v, pp. 336–37, 1894.

† Observations on the Geology of Adjacent Parts of Oklahoma and North West Texas, Proc. Nat. Sci. Acad. Phila., 1894, p. 63.

‡ Geology of North America, p. 17.

§ Originally published as *G. pitcheri* Morton. Prof. Brown informs me by letter that it is the form figured by Marcou, i. e. *G. forniculata* White.

‖ Originally published as *O. crenulimargo* Roemer by Prof. Brown. He informs me that he now regards it a variety of *Ostrea quadriplicata* Shum.

¶ See remarks on this species by Dr. Benj. F. Shumard, Trans. Academy of Science of St. Louis, vol. i, p. 587. He here states that its horizon is the Washita limestone and gives more light upon it than is contained in his original description of it in Marcy's Report on Red River.

The vertebrata from these beds strikingly resemble those described by Williston and Cragin from the Belvidere beds of Kansas with the exception of two species of Pycnodont fishes belonging to the genera Uranoplosus and Cœlodus, for which this is a new horizon.*

Concerning these vertebrates Prof. Cope† remarks:

"The three species of Pycnodont fishes were new to science, and they have a Lower Cretaceous facies. Plesiosaurus is represented by dorsal vertebræ only, but these are not of the Upper Cretaceous type. I have never found Lepidotid fish remains in the Upper Cretaceous of North America, while they are characteristically Lower Cretaceous and Jurassic in Europe. The only occurrence of Lepidotid fishes so far recognized in North America, is based on some teeth sent by Mr. Charles H. Sternberg in the Dakota sandstone of Kansas, and on the new species, *Macrepistius arenatus*, from the Trinity bed of Texas discovered by Prof. R. T. Hill. (See Journal of the Academy Natural Science, Philadelphia, vol. ix, Part 4). The crocodilion remains are undeterminable."

From the molluscan species it will be seen that these beds paleontologically more resemble the Washita division than the Fredericksburg. Furthermore, they show the same general association of molluscan species as do the Belvidere shales, and like them differ from the beds of the Central Texas region by containing vertebrates. That they are a southern extension of the Belvidere beds there can be no reasonable doubt.

The Comet Creek Bed.—Little is known concerning the isolated remnant of the Cretaceous formations at Comet Creek, in G county, Oklahoma, the only locality of the Comanche Cretaceous recognized as having been seen by Prof. Jules Marcou in his journey with the Pacific railway explorations.‡ According to this author this locality consists of a single stratum of "Gryphæate limestone" "five feet thick" containing one fossil species, the *G. pitcheri* of Marcou. This species has been found elsewhere only in the Washita division and is especially abundant in both the Belvidere shales of Kansas and the Preston beds of Texas. This is the fossil which Prof. Marcou figures so well as *Gryphœa pitcheri*§ Morton, but for which he himself later suggested the more appropriate name of *G.*

*The species of the genus Mesodon from Texas described by Prof. Cope with these fishes, as coming from Texas, belong to the Trinity division.—See New and Little Known Paleozoic and Mesozoic Fishes, Journal Academy of Natural Science, vol. x, Philadelphia, 1894.

† Proc. Phila. Acad. of Nat. Science, loc. cit., 243.

‡ See Geology of North America, p. 17.

§ He says, Geology of North America, page 38: "The drawings are very exact and were done from nature by Humbert, the most skilful artist for fossils in Paris."

Rœmeri,* and which White later described as *G. forniculata*, as called throughout this paper.

Inasmuch as these beds lie in the Kansas province, i. e., the region north of the Ouachita system of mountains, and is completely cut off from the Texas region by them, it is reasonable to infer, until the localities can be visited, that the Comet Creek bed is a part of the same general formation as those near by at Camp Supply and Belvidere.

The Tucumcari Region.—The Tucumcari exposures, as we shall call the New Mexican localities of the Cretaceous, are the most isolated of all the Comanche deposits, and, as we have shown, there is no possibility of tracing by stratigraphic continuity their relations with the main Kansas and Texas areas. They are two hundred and fifty miles southwest and west of the Belvidere and Comet Creek localities; about two hundred miles northwest of the nearest Texas localities in the breaks of the Plains on the headwaters of the Brazos, and three hundred miles north of the Kent localities in Trans Pecos, Texas. If there was stratigraphic connection between these localities across the intervening areas, it was forever destroyed by the great pre-Plains erosion, or obscured by the succeeding Plains sedimentation.

Yet paleontology again comes to our aid to show that the small thickness of Comanche Cretaceous preserved in this isolated area was intimately connected with the other outlying areas. It is unfortunate that in the following remarks we have not the benefits of the publication of the results of the field season spent by Prof. Alpheus Hyatt in this region in the year 1889. The writer has seen his collections, however, and has no fear in saying that, when published, they will substantiate the general proposition maintained in this paper. That he and every other modern writer holds these beds to be of Cretaceous age, and not Jurassic, as maintained by Prof. Jules Marcou, is also fully substantiated. We shall not enter into this controversy here. Aside from Prof. Hyatt's unpublished collection, three collections have been made from this region.

1. By Prof. Jules Marcou, who collected two species as follows: *Gryphæa tucumcari* Marcou, later figured by him as *Gryphæa dilatata* var. *tucumcarii*; and *Ostrea Marshi* Marcou.

2. A collection made by the writer, April 30, 1891, and now in the collections of Johns Hopkins University, a list of which was published in Science of July 14, 1893.

3. A collection made by members of the Texas Geological Survey, in the summer of 1891, a list of which as identified by Mr. T. W. Stanton of the U. S. Geological Survey, was published on page 208 of the third annual report of that survey.

* Proceedings Boston Society of Natural History, 1861, p. 95.

In addition Prof. Cragin has recognized from the Tucumcari collections of the Texas Survey two species which he had collected from Belvidere, *Cardita belviderensis* Cragin and *Pinna comancheana* Cragin. Mr. Stanton has also identified *Roudaria [?] quadrans* Cragin in the Tucumcari collections made by Prof. Hyatt, and *Trigonia emoryi* Con., *Protocardia texanum* Con., *Cardita belviderensis* Cragin, *Tapes belviderensis* Cragin, and Cyprimeria sp. from the collection made by the writer.

Counting all these known fossils, we have from the Tucumcari beds the following list of species of invertebrates:

Turbinolia texana [?] Conrad.
Ostrea Marshi, as determined by Marcou.
Ostrea quadriplicata Shumard.
Gryphæa dilatata, var. tucumcarii Marcou.
Gryphæa pitcheri Morton.
Exogyra texana Roemer.
Plicatula, species undescribed.
Neithea occidentalis Conrad.
Trigonia emoryii Conrad.
Protocardia multistriata Con.
P. texanum Conrad.
Cytherea leonensis Conrad.
Pinna comancheana Cragin.
Cardita belviderensis Cragin.
Tapes belviderensis Cragin.
Roudaria [?] quadrans Cragin.
Cyprimeria sp.
Turritella seriatim granulata Roemer.
Turritella marnochii White, or seriatim granulata Roemer.
Ammonites leonensis Conrad.

These species all come from the impure shaly beds below the highest escarpment of brown sandstone, which we shall elsewhere discuss under the Dakota, and above the unfossiliferous white sands, occupying a vertical range of about 115 feet in thickness.

Of the twenty species enumerated thirteen are also represented in the Belvidere beds, as follows:

Gryphæa dilatata var. tucumcarii Marcou.
G. pitcheri Morton.
Exogyra texana Roemer.
Plicatula, species.
Trigonia emoryii Conrad.
Protocardia multistriata Conrad.
Tapes belviderensis Cragin.
Pinna comancheana Cragin.
Cardita belviderensis Cragin.
Roudaria ? quadrans Cragin.
Turritella seriatim-granulata Roemer.
Turritella marnochii White.

The analogy between these fossils and those characterizing the Washita division is so striking that it hardly seems necessary to make comparisons of the species enumerated. The following are peculiar to and characteristic of the Washita division:

Turbinolia texana Conrad.
O. quadriplicata Shumard.
G. dilatata var. tucumcarii Marcou.
G. pitcheri Morton (var. not given).
Plicatula sp.
Trigonia emoryii Conrad.
Pinna comancheana Cragin.
Cardita belviderensis Cragin.
Protocardia texanum Conrad.
Turritella marnochii White.
Ammonites leonensis Conrad.

Of the remaining six, one, *Cytherea leonensis* Conrad, is a form which is reported in the Mexican Boundary Report from near Leon Springs. The writer has never seen this species *in situ*. *Ostrea Marshii* is a form which Dr. B. F. Shumard calls *O. subovata*, and which he has identified from his "Washita limestone," which is practically synchronous with the whole of our Washita division. Of this species he says:*

"I have before me specimens of *O. subovata* from Fort Washita, several localities in Grayson and McLennan counties, and from Mt. Bonnell, near Austin, some of them in a beautiful state of preservation, and have compared them most carefully with Marcou's figure of *Ostrea Marshii*, in the Geology of the U. S., without being able to detect any difference whatever of specific value. . . . I have also compared my specimens of *O. subovata* with an authentic example of *O. Marshii* from Europe, and regard them as being specifically distinct, as much so as we usually find in closely allied species."

Protocardia multistriata Conrad is a species of *Protocardia* which may occur in both the Fredericksburg and Washita divisions. The writer has specimens from the Denison beds of the Washita division which are indistinguishable from it.

This leaves only three species, *Turritella seriatim-granulata* Roemer, *Exogyra texana* Roemer, and *Neithea occidentalis* Conrad, which may have a common range into both the Washita and Fredericksburg divisions.

The absence of the rich fauna of the Fredericksburg and Glen Rose which constitutes the great thickness of the Central Texas section is conspicuous.

It must be apparent that the fossils from the Comanche Cretaceous at Tucumcari are nearly related to the faunas of the Washita division of North Texas, and to the Trans Pecos and Belvidere regions, and they show certain transitional conditions between the variations seen in the faunas of these extreme localities, such as the occurrence of species so far as known hitherto found in only one of the regions, such as *Turbinolia texana*, of El Paso region, *O. quadriplicata* Shumard, of the Central Texas region, *Ammonites leonensis* Cragin, of the Central Texas and Trans Pecos region, and *Pinna comancheana* Cragin, *Roudaria? quadrans* Cragin, and *Cardita belviderensis* Cragin, of the Belvidere region.

The age of the arenaceous beds underlying the first fossiliferous horizon of Tucumcari is still problematic. In previous papers the writer has noted their lithologic resemblance to the basement arenaceous Trinity littoral of the Comanche series of Texas.

* Trans. Academy of Science, St. Louis, 1860, vol. i, No. 4, p. 587.

The white sands between the Red Beds and Washita fauna are lithologically somewhat different from the Cheyenne sandstones, but it is an interesting fact hitherto unpublished, that they contain dicotyledonous leaves of at least one species identical with those of the Cheyenne sandstone, the *Sterculea Snowii* of Lesquereux. This specimen was collected by the State Geological Survey, and erroneously described,* as Prof. F. H. Knowlton has shown,† as a new species under the name *Sterculea drakei* Cummins. It was also erroneously published,‡ as having come "From the upper sandstone of the Tucumcari beds four miles west of Tucumcari Mountain, New Mexico, above the bed of blue clay, 'bed F' of Marcou's section."§ Mr. N. F. Drake in a recent letter to Mr. J. A. Taff,‖ as announced by the latter before the Geological Society of Washington, April, 1895, stated that he collected this particular specimen, and that it came from the basal sandstone below the molluscan-bearing beds and not from the Dakota above it. It is the writer's opinion that when these basal beds are fully studied, they may be found to represent the initiatory sediments of the Comanche sea upon the Red Beds in this region, like the Trinity sand of Central Texas, the Antlers sands of Southern Indian Territory, and the Cheyenne sandstone of Kansas, all members of the great initiatory littoral formation, marking epochs in the migration of the sea which, during the Comanche epoch, transversed them diagonally northward across the Great Plains Region.

A comparison of the two sections at Tucumcari and Belvidere which the writer has personally studied, reveal some common interesting general features. Both localities show topographic similarity in that they are remnantal buttes in the margins of the Plains. The summits of both sections are the mortar-bed-like rocks of the Tertiary Plains formation resting, through unconformity by erosion, on a sandstone of supposed Dakota age. Beneath this alleged Dakota sandstone in each locality are clay shales with marine fossils of the Washita division; below these molluscan-bearing shales are sands containing the dicotyledonous *Sterculea Snowii* Lesquereux, while the base of each is the Red Beds.

The observable differences between the Belvidere and Tucumcari localities are as follows: *G. dilatata* occurs at the base of the Washita beds at Tucumcari, while at Belvidere it ranges near their summit. The Tucumcari fauna contains above the

* Annual Report, Texas, State Geol. Survey, 1891, p. 210.
† American Journal of Geology, vol. ii, No. 4, p. 372.
‡ Geol. Survey of Texas, Third Annual Report, 1891, p. 210.
§ Ibid, p. 209.
‖ We are indebted to Mr. J. A. Taff for permission to use this information.

G. dilatata zone, *Ammonites leonensis* Conrad and *O. quadriplicata* Shumard, characteristic middle and upper Washita species of the Central Texas region, which do not occur at Belvidere. In general association the species of the Tucumcari locality have greater resemblance to that of the uppermost beds of the Washita division of the Central Texas section, while the common forms of the Belvidere beds, such as *Schlœnbachia peruvianus* and *Gryphœa Rœmeri*, are more common to the Preston or basal beds of the Washita. More minute studies of the range of species in the Tucumcari beds is necessary before any positive conclusions on these subjects can be stated.

The seventy-five feet of alleged Dakota sandstone overlying the fossiliferous beds of Tucumcari will be more fully discussed in a future paper.

The outlying beds of the Washita division are also found far southward in the Trans Pecos region of Texas at Kent,* El Paso and as far west as Arivichi in Sonora, where its fauna was reported by Gabb. We cannot here continue the presentation of the minute data concerning them, but they, together with the data we have given concerning the beds in Kansas, Oklahoma and New Mexico, all demonstrate the generalization we have before presented,† that the beds of the Washita division far overlapped interiorward those of the Trinity division. This study has enabled us to classify and understand the significance of the outlying areas of the Cretaceous in Oklahoma, New Mexico, and Trans Pecos, Texas, and their paleontologic relations as shown in the appended table.

The geology of these outlying areas of the Cretaceous preserved in the scarps of the Plains adds greatly to our knowledge of the distribution, variation, paleontology, and history of the beds of the Comanche series and of the progressive oscillatory conquest of the Great Plains region by the sea in Cretaceous time. The Belvidere beds have revealed the following additions to our knowledge of Cretaceous paleontology: First, a lower stratigraphic occurrence of the dicotyledonous Dakota flora than known, whereby we may now say that dicotyledons make their first appearance before the beginning of the Washita sub-epoch, instead of in the Dakota as hitherto believed. Second, a similar downward range in the geologic scale of the Icthyan vertebrates of hitherto supposed Upper Cretaceous range. Third, intermingling of these plants and fishes with molluscan species and other vertebrates of the Washita division such as has not hitherto been found in the Comanche series.

* See sections by E. T. Dumble, Bull. Geol. Soc. America, vol. vi, pp. 376–388, and American Geologist, vol. xii, p. 309.

† Bull. Geol. Soc. of America, vol. v, p. 332–338.

These beds represent the modified attenuated northern extension of the Washita division and probably a portion of the Fredericksburg division of the Comanche series of Texas, which, as we have previously shown, far overlapped to the northward those of the Trinity division. The beds of the later division have not been found north of the 34th parallel and there is every reason to believe that their original sedimentation did not extend north of this line. Neither are the remarkable limestones and accompanying forms of the great Caprina limestone of southern Texas represented in the outlying areas.

Known Occurrence of Species of the Outlying Areas of the Comanche Series.

	Washita.					Fredericksburg.	Trinity.
	Kansas.	Oklahoma.	New Mexico.	Trans Pecos, Tx.	Central Texas.		
Turbinolia texana Conrad	--	--	×	×	--		
Terebratula wacoensis Roemer	--	--	--	×	×		
Ostrea subovata Shumard	?	×	×	×	×		
Ostrea quadriplicata Shumard	--	×	×	×	×		
Gryphæa forniculata White	×	×	×	×	×		
Gryphæa pitcheri Morton	×	×	×	×	×		
G. dilatata var. tucumcarii Marcou	×	×	×	×	--		
Exogyra texana Roemer	×	×	×	×	--	×	
Exogyra plexa Cragin	--	--	--	×	×		
Plicatula incongrua Conrad	--	×	×	×	--		
Plicatula belviderensis Cragin	×	×	×	×	--		
Lima wacoensis Roemer	--	--	--	×	×	×	
Neithea occidentalis Conrad	--	×	×	×	×	×	
Avicula belviderensis Cragin	×	--	--	--	--		
A. leveretti Cragin	×	--	--	--	×		
Pinna comancheana Cragin	×	--	×	--	?		
Inoceramus comancheana Cragin	×	--	--	--	×		
Nucula catherina Cragin	--	--	--	--	--		
Trigonia emoryii Conrad	×	?	×	×	×		
Cardita belviderensis Cragin	×	--	×	--	--		
Protocardia texanum Conrad	×	×	×	×	×		
P. multistriatum Conrad	--	--	×	×	×		
Cyprimeria species	×	--	×	×	×		
Cytherea leonensis? Conrad	--	--	×	×	--		
Cytherea sp	×	--	--	--	×		
Mactra antiqua Cragin	×	--	--	--	--		
Corbula crassicostata Cragin	×	--	--	--	×		
Tapes belviderensis Cragin	×	--	×	--	--		
Roudaria quadrans Cragin	×	--	×	--	--		
Turritella seriatim-granulata Roemer	×	×	×	×	×	×	
T. marnochii White	--	--	--	--	--		
Trochus texanus Roemer	?×	--	--	--	--	×	
Ammonites leonensis Conrad	--	--	×	×	×		
Schlœnbachia peruvianus von Buch	×	×	--	×	×	×	
Sphenodiscus sp	×	--	--	×	×	×	

Art. XXII.—*The Relations of the Diurnal Rise and Fall of the Wind in the United States;* by Frank Waldo.

I. *Relative Rapidity of Diurnal Rise and Fall of Wind.*

An inspection of the curves indicating the diurnal change in the wind velocities shows usually at a glance whether the rise of the wind to the mid-day maximum takes place more rapidly or more slowly than the subsequent fall of the wind.

For January over nearly the whole of the United States the rate of fall of the wind is more rapid than the rate of rise toward the mid-day maximum. Still in the western U. S. there is a central region extending from northern New Mexico to Montana and a region in the extreme southwest in southern California and southwestern Arizona where the rise is more rapid than the fall; and in a number of places irregularly distributed the rates of rise and fall are equal; while in the eastern part of the U. S., in the Ohio valley, there is a small section where the rise and fall are about equal, and around this there is a narrow region where the rise is more rapid than the fall.

For July the fall of the wind is in general more rapid than the rise: but in the western U. S. there are regions, in western Colorado and eastern Utah, in northern Texas, Oklahoma and southern Kansas, and on the central and southern Pacific coast, where the rise is more rapid than the fall; while also in the eastern U. S., in central Ohio and at some places on the Atlantic coast the rise is more rapid than the fall. The places where the rise and fall are equal are not so numerous in July as in January.

For the Year, to the east of the medial meridian of the U. S. (about the 100° longitude) the fall of the wind after the mid-day maximum is more rapid than the rise preceding it: but to the west of this line the rise of the wind proceeds at a more rapid rate than the fall. There are, however, some exceptions to this rule. Over a limited region in southern Oregon and northwestern Nevada, and again in southeastern Arizona and southwestern New Mexico, the fall of the wind is more rapid than its rise. Also on the central Mississippi River and around Lake Erie the rise of the wind is more rapid than its fall.

II. *Period of Mid-day Rise of Wind.*

The duration of the period when a *decided* continuous rise of the wind occurs towards the nearly mid-day maximum

can be indicated in a general way for the various regions of the U. S.

For January immediately along the Mississippi River Valley there is a rise of wind during 6 hours. To the east of this there is a decrease to 4 hours at the north, along the Great Lakes, with a slight decrease to 5 hours at the center just east of the Alleghany Mountains, and in the extreme southeast of the U. S. But near the Atlantic coast there is an increase to 7 hours.

To the west of the Mississippi Valley there is a rather rapid decrease to 3 or 4 hours at the north. At the center there is an immediate increase to 7 hours on the 97th meridian, then a decrease to 3 hours at the 105th meridian in central Colorado, then a slight increase to 4 or 5 hours, then another decrease to 3h. in central Nevada, from which there is an increase to 7h. or more on the Pacific coast. At the south there is a decrease to 4h. in central Texas, then an increase to 7h. in southern New Mexico, then a decrease to 3h. in southern Arizona, and an increase to 5h. on the South Pacific coast. There seems to be about the same time of rise on the not exposed Pacific and Atlantic coasts north and south; and also on the eastern and western Gulf Coast.

For July, along the 92d meridian, which lies just a little to the west of the Mississippi River, the time of rise of wind is about 7 hours. To the west of this there is: at the north, an increase to 9h.; at the center at first little change and then a slight increase to 8h., which, on the Pacific slope, increases suddenly to 11h.; at the south, at first a rapid increase to 10h. and then a rapid decrease to 5h. in southern Arizona, and finally a return to 7h. on the southern Pacific coast.

To the east of the central 7 hour region, of longitude 92° passing through Duluth, there is: at the north an increase to 9h. on the Upper Lakes, a return to 7h. on the Lower Lakes, and an increase to 9h. on the Atlantic coast; at the center an increase to 8h. for most of the region and to 9h. on the coast, but with a relapse to 7h. just east of the Alleghany Mountains; at the south there is an increase to 9h. on the Atlantic coast, but along the Gulf of Mexico a decrease to 5h.

On the eastern Gulf coast the rise is for 5h. and at the western coast it is 10h. On the Atlantic coast for exposed stations there is a decrease from 10h. at the north to 5h. at the south of Florida; while for the stations where the land influence is more predominating there is an increase from 8h. at the north to 10h. at the south. On the Pacific coast there appears to be a decrease from about 10h. at the north to 7h. at the south for the better land exposures.

For the Year there is along about the 92d meridian, that is in the Mississippi River Valley, a continuous decided rise during 7 hours.

To the west of this there is a gradual decrease to about 5 hours at the north; very little change but probably a slight increase to 8h. near the coast at the center; a slight but rapid increase to 8h. to the south of the center, but in the extreme southwestern U. S. a decrease to 6h., and in central south Texas a local minimum of 4 hours.

To the east of the Mississippi River there is: at the north a slight increase to 8 hours in the Upper Lake region, with a decrease to 5 hours in the Lower Lake region and an increase again to 7h. or 8h. near the Atlantic coast; at the center the rise of wind continues for 6h. except near the Atlantic coast, where it increases to 7h.; at the south there is a rise during 7h. or 8h.

At the places of unusually high exposure for the anemometers on the land, and also for the water exposures, the time of rise of the wind seems to differ but little from that of the ordinary land exposures for the same region.

III. *Average Rate of Increase of Wind to the Maximum.*

The average of rise in miles per hour during the period of rapid rise, which extends in most cases from about sunrise tc the time of maximum wind, presents regional characteristics.

For January there is a central region crossing the U. S. about along the 100th meridian in which the rise is at the rate of 0·4 miles per hour. To the east of this the rate of rise is about 0·3 miles per hour: with a local increase to 0·4 m. p. h. in eastern North Carolina and Virginia, and to 0·5 m. p. h. on the western shores of Lakes Michigan and Huron. Also directly in the Mississippi River Valley there appears to be a regular decrease from about ·35 m. p. h. on the upper Mississippi to 0·1 or less on the lower Mississippi.

To the west of the 100th meridian there is a slight gradual decrease to 0·3 m. p. h. in the northwestern U. S.; but there is an increase to over 1·00 m. p. h. in the extreme southwestern U. S., and in fact a maximum of 1·6 m. p. h. is reached in Arizona. In most of the southwestern U. S. west of the 100th meridian and south of the 42° parallel the rate of increase of wind is over ·50 m. p. h.

For July the average rate of increase of wind is about 0·5 miles per hour along the 97th meridian. To the west of this medial region there is a decrease to 0·40 m. p. h., at the north inland, and to less than 0·3 m. p. h. on the coast: at the center and the south a slow increase to about 0·6 m. p. h., and then a

very rapid increase to 1·1 m. p. h. or 1·2 m. p. h. as the extreme southwest and the western coast is approached. On the Pacific coast there is an increase from less than 0·3 m. p. h. at the extreme north to 1·2 m. p. h. and 1·1 m. p. h. at the center and south.

To the east of the central meridianal region of 0·5 m. p. h. there is probably little change on the average at the north, although there is some lack of uniformity in the data for various stations, the rate of increase varying from 0·4 to 0·6 m. p. h. At the center and south there is a slight decrease to 0·4 m. p. h. with a small sectional local increase to 0·6 m. p. h. in the central Ohio River Valley, and local decrease to 0·3 m. p. h. in the lower Mississippi Valley.

There is a local increase to 0·7 m. p. h. in southeastern Texas, and a decrease to 0·4 m. p. h. on the southeastern coasts of the United States.

For the Year along about the 95th meridian (slightly to the east of it at the north and a little to the west of it at the south), the rate of rise of the wind is 0·5 m. p. h. To the west of this at the north there is at first a small local increase to 0·6 m. p. h. and then a gradual decrease to 0·4 m. p. h.

At the center and south there is at first a slight, and then, at the extreme west, a very rapid increase to about 0·9 m. p. h. on the coast. At the south there is at first a slow and then a rapid increase to 1·1 m. p. h. or 1·2 m. p. h. with a further decrease to 1·0 on the coast.

To the east of the 95th meridian there is at the north a rapid decrease to about 0·35 m. p. h. which is preserved to the Atlantic; but there is some disagreement for individual stations. At the center there is an increase to 0·7 m. p. h. or 0·8 m. p. h. in the middle Ohio Valley and then a decrease to 0·3 for the exposed Atlantic coast stations. At the south there is a decrease to 0·3 m. p. h. on the lower Mississippi, and then an increase to ·45 m. p. h., which extends quite to the Atlantic coast.

Princeton, N. J.

Art. XXIII.—*Stratigraphy of the Kansas Coal Measures;* by Charles Rollin Keyes.

Two papers* have been published recently which for several reasons should receive attention at this time. In the first place, both accounts are soon again to appear in another form. In the second place, both articles consider at some length questions regarding the deposition of the Coal Measures of the Interior basin that have been lately discussed rather fully in the description of the Carboniferous formations of Iowa and Missouri. The salient points of the discussion of the Iowa and Missouri regions have been so misinterpreted in their application to the Kansas field and the conclusions thus drawn are so misleading, that very erroneous inferences might be deduced concerning the original views expressed were not some of the discrepancies pointed out. In this connection it may not be out of place also to set forth some new information which has been obtained since the reports of the two states mentioned were issued, and to call attention to the observations recently made in Kansas which go to substantiate fully certain opinions previously urged† concerning the subdivisions of the Coal Measures of the Western Interior basin.

In considering the conditions of deposition of the Coal Measures very much more has been assumed for the views presented in the Iowa report than was there expressed. At first sight it would be difficult to understand how this could happen; but upon reference to the hypothesis advanced for the Kansas rocks it becomes clear. Great stress has been placed upon the present dips of the strata and diagrams are offered in explanation. But it appears that the importance of these dips has been overrated in its application to the hypothesis advanced and in its militating against the other view. The inclination of the strata at the present time is in reality of small import, for since the beds were first laid down many changes in dip have doubtless taken place and profound erosion has obscured much of the evidence that would be of value as supporting the hypothesis. There is one point of considerable consequence, however, which has been entirely overlooked. The observed dips of the beds in Kansas are apparent dips and do not necessarily represent the true direction of inclination. That they are westerly slants is because the cross-sections were made along streams which flow eastward. In dissenting from the generalizations made for the country east of the Missouri river, special

* E. Haworth: Kansas Univ. Quart., vol. iii, pp. 271–295; Lawrence, 1895.
† Iowa Geol. Sur., vol. ii, 1893; also Missouri Geol. Sur., vol. iv, 1894.

emphasis is placed on the fact that in passing from the east to the west in Kansas the observations made are not in accord with those of Missouri and Iowa. In going in that direction—west—they most assuredly would not. That would be about the same as if the sections in Iowa were constructed in a somewhat north and south direction or in a way that would be parallel to the ancient shore-line instead of at right angles to it.

In eastern Kansas the original seaward slant of the beds was evidently to the northwest and a little farther to the west it was perhaps more nearly northward. In the states of Iowa and Missouri the observations were made from very different points of vantage—from the east or north sides of the bay-like expansion. More specifically, in looking towards the sea, straight out from the shore, the direction in northern Iowa would be to the south or southwest; in southern Iowa and northern Missouri directly west; in southwestern Missouri northwest. The reason is this: the Western Interior coal basin occupied a broad shallow depression, and the Carboniferous waters consequently filled a wide semi-circular bay opening to the westward.

In the Iowa report it is not stated, as is set forth in the recent paper, that the coastal area was a region of greater subsidence than the oceanic. Nothing is said specifically regarding the relative rates of uprising or downsinking of the two districts; but it is stated that the oscillations affected very wide areas, and even, perhaps, approached in character continental elevation and depression. Of course considerable stress was placed upon the movements of the shore lines; for the reason that these are the present measures of the changes of the sea with reference to the land. The area being so broad and so shallow was particularly susceptible to all changes of relation between the land and water; and comparatively slight vertical movements would have produced great alterations in the extension of the sea.

Lately it has been conclusively shown that during the latter part of the Lower Carboniferous (Mississippian) the Interior basin was an area of uprising. The old shore must have extended from the present northwest corner of Iowa in a curved line through Des Moines, Kansas City and southwestward through Kansas into Oklahoma territory. It probably even extended farther to the west, but of this there is no evidence at present. At the time of greatest depression, or when the sea encroached most on the land, the border line was extended eastward to beyond the present position of the Mississippi river and from St. Louis extended southwestward over a considerable part of the area now forming the northwestern flank of the Ozark uplift. Even during the deposition of the

Coal Measures there is abundant evidence of many minor oscillations and special attention has been called* to a number of them. With the existence of such conditions as these the present dips lose much of their significance.

The important point is not so much the absolute dip but the slant of the strata with reference to the Coal Measure floor. When this is taken into consideration it doubtless will be found that the estimates usually placed upon the thickness of the Coal Measures are excessive, and that the common figures, which for Missouri have been 2000 feet and now for Kansas some 2800 feet, are doubtless very much too great. As evidence of this a diamond drill core taken out of a well at Kansas City showed a typical mica schist at a depth of 2400 feet, indicating that the entire Paleozoic had been passed through at about 2300 feet below the base of the Upper Coal Measures at that point.

It may be concluded from what has just been said, from the data presented in the two recent papers on the Kansas Coal Measures, and from what is known of the field relations of the Carboniferous formations in western Missouri and southeastern Kansas, that the four arguments in the article mentioned, which are set against the explanations offered for the deposition of the Coal Measures in the eastern and larger part of the basin, are not only invalid but the evidence itself upon which they rest disproves them. Viewed in the proper light, the Kansas rocks present identically the same stratigraphic features as do those of Missouri and Iowa.

Regarding the subdivisions† of the Coal Measures, it is of interest to learn that the same line of division has been independently adopted in Kansas which had been proposed a short time previously in Iowa and Missouri. Instead of a different classification for each state and a different dividing line for each locality, perhaps, the present selection now makes the subdivisions uniform for the whole Western Interior coal basin.

The objections raised‡ to the diagrams representing the stratigraphy of the Coal Measures in Iowa§ are not so serious, nor the ideas which are graphically represented such wide departures from the commonly accepted views, as the Kansas author has stated. In fact the attention is called to a certain class of phenomena which are, unfortunately, too frequently overlooked in stratigraphical work. The manifest object of the diagrammatic representation in the Iowa reports is to show that while

* Iowa Geol. Sur., vols. i and ii; also Bull. Geol. Soc. America, vol. ii, pp. 277–242, 1891.

† Haworth: Division of the Kansas Coal Measures, Kansas Univ. Quart., vol. iii, pp. 291–295; Lawrence, 1895.

‡ Kansas Univ. Quart., vol. iii, p. 291; Lawrence, 1895.

§ Iowa Geol. Sur., vol. i, pp. 117–118; Des Moines, 1893; also ibid., vol. ii, pp. 161–162; Des Moines, 1894.

the "Lower" and "Upper" Coal Measures do have a relation of one above the other and from a mining standpoint of an upper and a lower member, they do not hold positions indicating that as a whole the one is geologically older than the other, or that the lower was deposited before the upper. On the other hand, the facts show clearly that the terms lower and upper are misnomers in the sense that they are usually used, carrying with them as they do the idea of relative age. Moreover, along the great bedding planes marginal sediments were laid down at the same time as thalassic deposits were formed farther out from the shore. Therefore, as a line for the separation of the Coal Measures into two subdivisions, into a productive and a barren series, as a line which under existing conditions is of practical use in mining operations, one which also indicates the first marked physical and faunal changes in the sequence of strata in passing in a seaward direction from the ancient margins of the basin, the first great limestone met with was selected as the most reasonable, natural and convenient horizon. For this reason, it was stated* that in considering the Coal Measures as a whole, two tolerably distinct classes of sediments were readily recognized: (1) the marginal or coastal deposits, and (2) the beds laid down in the more open sea. These two categories are sharply contrasted lithologically, stratigraphically and faunally.

The first category is characterized by the rocks being predominantly argillaceous shales and sandstones, with practically no limestones. The individual beds usually are very limited in extent, and replace one another in rapid succession, both laterally and vertically. The sandstones often form great lenticular masses, sometimes deeply channeled on the upper surface, the excavations being filled with Coal Measure clays. These and many other phenomena attest a constantly shifting shore line and shallow waters. The fossils contained are nearly all brackish water forms, or shore species. Remains of pelagic organisms are not numerous.

On the other hand, the second class of deposits is made up largely of calcareous shales, with heavy beds of limestone. The layers are evenly bedded, and extend over very considerable distances. The faunas are chiefly composed of strictly open-sea forms.

With this idea of the Coal Measures of the Interior basin, the limits of the two formations in Iowa and the districts to the south assume somewhat different lines from those which have been commonly recognized.

The geological cross-sections recently made in central Iowa

* Missouri Geol. Sur., vol. iv, pp. 80–82; Jefferson City, 1894.

show clearly that the thick limestone of Winterset may be regarded as the base of the "Upper" Coal Measures. Coastal sediments carrying workable seams continue up to this line. Above it, open-sea deposits abruptly replace the former, and the coal veins are almost entirely wanting. This is admirably shown in the sections along Middle river in central Iowa, where Tilton* has gone into details on the subject. In one direction the course of the outcrop of the great limestone of Winterset is northwestward from the typical locality. It passes from Madison county through Guthrie and soon is lost beneath the Cretaceous. In the opposite direction it has been traced southward to the southern boundary of Iowa. In Missouri it appears to be continued by what is known as the Bethany limestone, which sweeps southward and then southwestward in a broad arc into Kansas. At Kansas City it seems to be represented by one of the principal beds exposed in the bluffs at that place. In Kansas Haworth† has just announced that he has traced what he calls the Erie or Triple limestone across the state in a southwesterly direction from Kansas City into Oklahoma territory; and that he has correlated it with the Bethany limestone of Missouri. With the recognition of these facts the base of the Upper Coal Measures has been traced over all of the Western Interior coal basin.

The appellation Bethany limestone for the basal formation of the Upper Coal Measures may be extended somewhat, so as to include more than No. 78 of the Broadhead section in Missouri and may be made to cover several of the limestone beds above the layer to which the term Bethany Falls was originally applied, for the reason that these layers are separated from the main bed only by thin, unimportant seams of shale. Thus it appears that the Winterset limestone of Iowa and the Erie limestone of Kansas are but extensions of the Bethany limestone of Missouri as now understood; and as the latter was the first to be recognized and to receive a specific geographical name, it has priority and must therefore supplant the other terms proposed.

* Iowa Geol. Sur., iii, pp. 135–146; Des Moines, 1895.
† Kansas Univ. Quart., vol. iii, pp. 293; Lawrence, 1895.

ART. XXIV.—*On the so-called Schneebergite;* by A. S. EAKLE and W. MUTHMAN.

IN the year 1880, A. Brezina* published a short announcement, "Ueber ein neues mineral, den Schneebergit," which was found on the Bockleitner Halde at Schneeberg in Tyrol. A qualitative analysis by H. Weidel gave as the principal constituents antimony and calcium, so Brezina supposed it might be a second modification of romeite or romeine, which according to Damour should have the formula $Sb_2O_5 . Sb_2O_3 . 3CaO$. Groth in his "Tabellarische Uebersicht der Mineralien" gives as the most probable formula for romeite $CaSb_2O_4$ and for schneebergite $Ca_2Sb_2O_7$, making this last identical with atopite.

A quantitative analysis of the schneebergite had not been made, so it appeared to us desirable to make one with a small amount of clean material. The mineralogical collection here contains a series of specimens of this rare mineral from Schneeberg, the greater part of which were collected at different times by von Elterlein during his study of the mineral deposits of that locality.

Most of the mineral appears as crystalline aggregates upon the ore, which latter consists of a mixture of magnetite, zincblende and chalcopyrite; the gangue mineral is massive quartz. The aggregates are partly kidney-shaped and consist of rounded crystal grains, with scarcely recognizable form. The color varies from honey-yellow to bright wine-yellow; the surface is often brown from a slight decomposition, the color being due to a thin coating of iron hydroxide. The perfectly fresh, undecomposed crystals are isotropic and occasionally show weak and abnormal double refraction, especially when they contain inclusions of fine particles of the ore.

On other ore-specimens the mineral appears as thin coatings or as a deposit; occasionally can well defined crystals be observed, all of which show the single form of the octahedron. The crystals are generally accompanied by calcite and breunerite, from which the mineral has evidently originated, as has been shown by v. Elterlein;† commonly the schneebergite surrounds the calcite, if it has not entirely replaced it. The paragenesis can be followed still better in sections under the microscope. It can be seen that the calcium-iron carbonate changes at first to a light yellow, double refracting mineral of indefinite composition, which by further change becomes granular and isotropic and finally passes into the pure schneebergite.

* Verhandl. d. k. k. geolog. Reichsanstalt, 1880, 313.

† Jahrbuch der k. k. geolog. Reichsanstalt, 1891, xli, 336; Zeitschr. für Kryst., xxiii, 283.

Some difficulty was experienced in isolating the material for an analysis and extreme care was necessary in order to get a perfectly pure product. The separated particles of ore fell easily by weak pressure with an agate spatula into single isotropic crystalline grains; a microscopical examination of this coarse powder showed an accompanying mixture of magnetite, zincblende, irregular fragments of milk-white quartz, calcite and almost opaque, unknown black particles of a mineral which was unattacked by acids, apparently some silicate; all of these impurities were present only in very small amounts and made at most 5 per cent of the total weight. The material was first digested with dilute hydrochloric acid and afterwards nitric acid was added and, after a short time, warmed in order to be sure of the decomposition of any sulphide present; the granular crystals of schneebergite are not attacked if the acid is sufficiently dilute. The well-washed and dried residue still contained quartz and the black particles, but these were removed mechanically and about 0·4 gr. of the mineral was obtained, which in respect to purity was all that could be desired.

The specific gravity was first carefully determined by means of a pycnometer; the amount of substance used was 0·4110 gr. and the specific gravity found was 3·838 (the average of three weighings from 3·823–3·848). Weidel found with 0·17 gr. the gravities 3·9, 4·1 and 4·3. As the amount of mineral was so small, a qualitative analysis was conducted in a quantitative way according to Weidel's results, who, as above stated, found antimony and calcium as the principal elements. The material was fused with potassium and sodium carbonates, with the addition of some nitric acid (in order to prevent the reduction of the antimony); the fused mass was dissolved in hydrochloric acid and there resulted a liquid, colored yellow by the iron present, which contained a substance having the exact appearance of silica. On the addition of hydrogen sulphide a deep brown precipitate was formed, which showed when examined, besides much sulphur from the oxidation of the hydrogen sulphide by the salts of iron, nothing but silica and some platinum, which last evidently came from the fusing-crucible, as fusions containing saltpeter will always attack platinum somewhat. Neither antimony, bismuth nor copper, which Weidel found, were present.

Further analysis of the filtrate gave only iron and calcium and the amounts were Fe_2O_3 32·33 per cent and CaO 32·58 per cent. An exact determination of the silica could not be made because it was partly used in the qualitative analysis of the precipitate. Professor Groth kindly placed at our disposal more of the material from the museum collection and

about 0·2 gr. of this was prepared. To remove the impurities, the material was treated with stronger hydrochloric acid, which also slightly attacked the schneebergite with the separation of silica. An analysis of the carefully cleaned material gave SiO_2 35·45 per cent and Fe_2O_3 32·11 per cent. The formula for this composition exactly tallies with that of a lime-iron garnet, as the following analyses show:

	Found.		Calculated for
	I.	II.	$3CaO . Fe_2O_3 . 3SiO_2$.
SiO_2	----	35·45%	35·43
Fe_2O_3	32·33	32·11	31·50
CaO	32·58	----	33·07

It follows from this examination, with certainty, that the schneebergite in the collection here, of which there is a whole series coming from different sources, is nothing more than a very pure lime-iron garnet, topazolite. The ore specimens came from the same locality as those described by Brezina and analyzed by Weidel. In respect to the color, hardness, microscopic relations, crystal form and the iron and calcium content, our mineral exactly coincides with that described by Brezina, so we make the supposition that the schneebergite is a garnet of the above composition. Our mineral fused in the blast flame to a dark brown liquid, while Brezina gave his as infusible. Our supposition is supported also by the circumstance that Brezina described the material as insoluble in acids; calcium salt of an oxy-acid of antimony would naturally be easily dissolved in strong hydrochloric acid. Apparently, on account of the small amount of very impure material which Weidel had, a mistake was made in the qualitative analysis.

The occurrence is exceedingly interesting, as garnet is seldom found in simple octahedra, and, until the present, a completely non-aluminous topazolite, with the exception of that from the Mussa Alp, has not been observed. The iron precipitate was treated with pure freshly-prepared sodium hydroxide, but no trace of aluminum was found; also the mineral contained no magnesia.

Munich, Bavaria, May, 1895.

Art. XXV.—*Native Sulphur in Michigan;* by W. H. Sherzer.

During the past year interesting deposits of sulphur have been discovered in the Upper Helderberg limestone, of Monroe county, Michigan, of which, it is believed, no report has yet been made. Native sulphur has not been recognized as

one of the minerals of this state, although as early as 1865 Prof. E. A. Strong collected from the gypsum beds of Grand Rapids a quart, or more, of platy particles, which he forwarded to Dr. Alexander Winchell, previously State Geologist.

The present locality is in the northern part of the county, upon the line of the Lake Shore and Michigan Southern R.R., one mile west of the village of Scofield. Here a quarry was opened some three years ago by the Michigan Stone & Supply Co., of Detroit, the rock being crushed and used mostly for macadamizing purposes. The bed-rock is overlain with from four to seven feet of soil and blue bowlder clay and its surface is scratched and grooved by glacial action. Channels and large "sink-holes" have been dissolved out by the water from the surface. The upper four feet of this bed is a grayish impure limestone, considerably "jointed," made up of fine, closely compacted layers, frequently contorted and banded with carbonaceous matter. It contains, in places, great numbers of small, obscurely defined fossils. This passes into a compact dolomitic limestone, from seven to eight feet in thickness, beneath which lies the so-called "sulphur-bed." This is a stratum of yellowish-brown impure limestone, varying in thickness from one to three feet and having but little dip. It contains brachiopods, corals and bryozoa and considerable carbonaceous material, here and there giving a strong oily odor. Wherever exposed to view it is seen to be cavernous in structure, the pockets varying in size from a fraction of an inch up to three feet. The larger ones are flattened and lie with their longer axes parallel to the plane of the bed, as though dissolved out by water flowing along the bed, rather than from above. Just beneath this "sulphur bed," and quite sharply separated from it, is a seam of bluish-gray, gritty, siliceous lime-rock, varying in thickness from one to three feet. This is curiously streaked with flexuous, but approximately vertical channels, lined with brownish, carbonaceous material, suggestive of the remains of fucoid stems. Under the magnifier the entire rock is seen to be finely porous and to consist of sand grains embedded in the calcareous paste. Passing downward, the rock becomes more of the nature of a sandstone and is said to become softer. The "sulphur bed" is thus seen to lie from sixteen to eighteen feet below the surface between a compact, dolomitic limestone and a calcareous sand rock. The pockets in the bed, above described, are lined with scalenohedrons of calcite, or tabular crystals of celestite, or both together. In some places the latter mineral becomes a chocolate brown. The sulphur generally occurs in bright lustrous masses towards the center of the cavity, intermatted frequently with the above minerals. Fragments as large as one's fist are

readily removed. Some of the smaller cavities contain nothing but sulphur and one was found filled with selenite crystals. About an acre of this bed had been removed when the locality was visited and from this the superintendent estimated that one hundred barrels of pure sulphur had been obtained.

It becomes a matter of interest to speculate upon the source of the mineral, since sulphur is so commonly associated with volcanic phenomena. At Grand Rapids it has, without doubt, resulted from the decomposition of the calcium sulphate, but no deposits of gypsum are known in this part of the state. That it was brought to the place of deposition in some form by water, along with the celestite and calcite, admits of no doubt. Although the overlying limestone contains a few cavities, but few of them contain any of the sulphur, and these are situated very near the sulphur bed. The underlying rock is still more free from the mineral, so it seems that the water must have been introduced from the *side*. At one end a stream of water was found entering the quarry at the level of this bed, highly charged with hydrogen sulphide and depositing a considerable quantity of the white precipitate of sulphur over the rocks and weeds. Some distance from where the water enters, this precipitate begins to assume a slightly yellow tinge, and upon breaking open the larger masses a nucleus of crystalline sulphur may occasionally be detected. Similar masses were found in some of the cavities, the outer portion having a lightish-yellow, mealy appearance, while the interior is solidly crystalline. The well water of the entire region is said to be charged with this same gas and it seems highly probable that the sulphur has resulted from its decomposition. Not unfrequently masses of the sulphur are found, however, of which the outer surface is vesicular, as though corroded by some solvent. Still, not believing that the hydrogen sulphide has been or could be formed directly from the action of the water upon the native mineral, it remains to consider its source. In many instances this gas is formed from the decomposition of iron pyrite, or marcasite, in the rocks, the iron being converted into an oxide and the sulphur obtaining its hydrogen from the water. No trace of these minerals, however, was detected in any of the rocks, although it is possible that they may occur in sufficient quantities farther back. The presence of so much carbonaceous matter in the bed itself, as well as in the rock above and below, indicated by the color and odor, leads me to strongly suspect that the gas has resulted from the decay of organic remains, animal or vegetable, or both.

Ypsilanti, Mich., July 12th, 1895.

ART. XXVI.—*On the Double Salts of Cæsium Chloride with Chromium Trichloride and with Uranyl Chloride;* by H. L. WELLS and B. B. BOLTWOOD.

NEUMANN* has made an extensive investigation of the double salts formed with chromium trichloride and the chlorides of several other metals, not, however, including cæsium. He obtained a violet double salt in each case with ammonium, potassium, rubidium, beryllium and magnesium, corresponding to the general formula, $2M'Cl.CrCl_3.H_2O$, while with lithium, sodium, calcium, strontium, barium, zinc and cadmium he was unable to prepare any double compounds. The double fluorides, $2NH_4F.CrF_3.H_2O$, and $2KF.CrF_3.H_2O$, which are analogous to Neumann's salts, have been mentioned by Wagner,† who also prepared the compounds $4NaF.2CrF_3.H_2O$ and $3NH_4F.CrF_3$. The existence of the latter salt has been confirmed by Petersen.‡

Since Neumann had not prepared any cæsium-chromium chloride, and because, from the well-known comparative insolubility of cæsium double salts, it seemed possible that a greater variety of compounds would be obtained with this than with other metals, we have undertaken an investigation in this direction. As the result of a systematic search, however, we have added only a variation in water of crystallization to Neumann's general formula.

Two salts have been obtained. One of these, $2CsCl.CrCl_3.H_2O$, is violet in color, corresponding exactly to Neumann's compounds, while the other, $2CsCl.CrCl_3.4H_2O$, is green. The violet salt was prepared by saturating warm aqueous solutions containing various proportions of the two simple chlorides with gaseous hydrochloric acid. The green salt was obtained from cold solutions by the use of hydrochloric acid, and without its use by evaporation over sulphuric acid.

The salt $2CsCl.CrCl_3.H_2O$ forms aggregates of very minute crystals of a magnificent red-violet color. It is stable in the air and does not lose its water at 160°. It is very slowly soluble in cold water, forming a green solution from which the green salt is deposited upon evaporation at ordinary temperatures. The four crops analyzed were prepared with amounts of cæsium chloride and chromic chloride varying from 15 g. of the first and 50 g. of the second to 50 g. of the first and 10 g. of the second. Gaseous hydrochloric acid caused a deposition of the salt from warm solutions. The products, after careful

* Liebig's Annalen, ccxliv, 329. † Berichte, xix, 896.
‡ J. pr. Ch., II, lx, 52.

drying with paper and over sulphuric acid, gave the following results upon analysis:

	A.	B.	C.	D.	Calculated for $2CsCl . CrCl_3 . H_2O$.
Cæsium	50·31	49·72	49·64	----	51·79
Chromium	10·44	10·53	10·68	10·70	10·15
Chlorine	34·65	34·77	34·37	----	34·56
Water	4·11	5·12	----	----	3·50
	99·51	100·14			100·00

The salt $2CsCl . CrCl_3 . 4H_2O$ is deposited from cold concentrated solutions in the form of green, apparently monoclinic crystals. It is somewhat deliquescent, very soluble in water and loses no water in the desiccator over sulphuric acid. At 110° it readily loses three molecules of water and is converted into the violet salt. Three crops analyzed were prepared as follows: Crop A, by evaporating a solution of 50 g. cæsium chloride and 25 g. of chromic chloride; Crop B, by dissolving the violet salt in water and evaporating over sulphuric acid; Crop C, by cooling a concentrated solution of 50 g. of each chloride with the aid of ice and saturating it with hydrochloric acid. The results were as follows:

	A.	B.	C.	Calculated for $2CsCl . CrCl_3 . 4H_2O$.
Cæsium	46·40	46·13	46·73	46·86
Chromium	9·80	9·53	10·79	9·19
Chlorine	31·30	31·14	----	31·27
Water	----	----	----	12·68

A determination was also made of the water lost at 110°:

	Found.	Calculated for $3H_2O$ in $2CsCl . CrCl_3 . 4H_2O$.
Water	9·90	9·51

The variation in color of the two salts that have just been described is interesting in connection with the violet and green modifications of chromic salts in general, which have furnished the ground for much investigation and discussion. In the case under consideration the transformation from one color to the other is accomplished by the addition or subtraction of water. It seems highly probable, however, that the change in water is accompanied by a fundamental change in the molecular structure, because the violet salt, containing the smaller amount of water, is very much more slowly soluble in water than the green salt, forming like the latter a green solution. We have found that the whole of the chlorine, in the cold green solutions of these cæsium salts, is not precipitated as silver chloride,

thus showing that they agree in this respect with other green solutions of chromic chloride.

It is a curious circumstance that the green chromic sulphate has been considered* to contain less water than the violet modification, while with our cæsium salts exactly the reverse is true, the green salt containing the larger amount of water. It is also remarkable that, while violet chromic solutions are turned green by heat, our violet salt, nevertheless, is produced in hot solutions and the green salt in cold ones. The theory advanced by Krüger and maintained by van Cleeff† that the green color of chromic sulphate solutions is due to the formation of a basic salt and free acid or an acid salt, seems hardly applicable to the green cæsium salts, ince it crystallizes from solutions saturated with hydrochloric acid in which a basic salt would seem to be an impossibility. In view of these apparently conflicting facts, it seems necessary to draw the conclusion that the differences in color exhibited by chromic compounds and their solutions are due to more than one cause, probably to the formation of basic salts in certain cases, and also, in other instances, to a change in water of crystallization which is evidently accompanied by a molecular transformation.

Uranyl chloride and cæsium chloride.—A careful series of experiments with cæsium chloride and uranyl chloride has resulted in the discovery of but a single salt. This compound, $2CsCl . UO_2Cl_2$, corresponds, except that it contains no water, to the previously described salts, $2KCl . UO_2Cl_2 . 2H_2O$, $2KBr . UO_2Br_2 . 2H_2O$, $2NH_4Cl . UO_2Cl_2 . 2H_2O$ and $2NH_4Br . UO_2Br_2 . 2H_2O$, but some fluorides of other types have been described.

The compound under consideration forms apparently orthorhombic, yellow crystals which are usually small and blade-like in shape. The products used for analysis were made under the following conditions: Crop A, by making a concentrated aqueous solution of 10 g. of cæsium chloride and 50 g. of uranyl chloride, then running in gaseous hydrochloric acid until crystals began to form and cooling; Crop B, by the same method as above, using 50 g. of cæsium chloride and 10 g. of uranyl chloride; Crops C and D, by spontaneous evaporation of solutions containing 50 g. of cæsium chloride and 15 g. of uranyl chloride; and E, by the evaporation of a solution of 15 g. of cæsium chloride and 50 g. of uranyl chloride. The results were as follows:

	A.	B.	C.	D.	E.	Calculated for $2CsCl . UO_2Cl_2$.
Cs	39·43	39·63	40·07	....	....	39·15
UO_2	40·37	41·14	40·96	41·85	43·39	39·95
Cl	20·63	21·17	20·85	20·84	20·59	20·90

* Vide van Cleeff, J. pr. Ch., II, xxiii, 58. † Loc. cit.

The cæsium chloride used in this investigation was from a liberal supply of cæsium and rubidium salts presented to this laboratory, for the encouragement of scientific research, by Herr E. Merck of Darmstadt, Germany, and we wish to express our sincere thanks to him for his generosity.

Sheffield Scientific School,
New Haven, Conn., June, 1895.

Art. XXVII.—*On two new Meteorites;* by E. E. Howell. With Plate IV.

1. *The Cherokee Meteorite.*

This meteorite was found in March, 1894, by Mr. S. B. May a few hundred yards from the Clarkson gold mine, two and one-half miles east of Cherokee Mills, and about five miles S.W. of Canton, Cherokee Co., Ga.

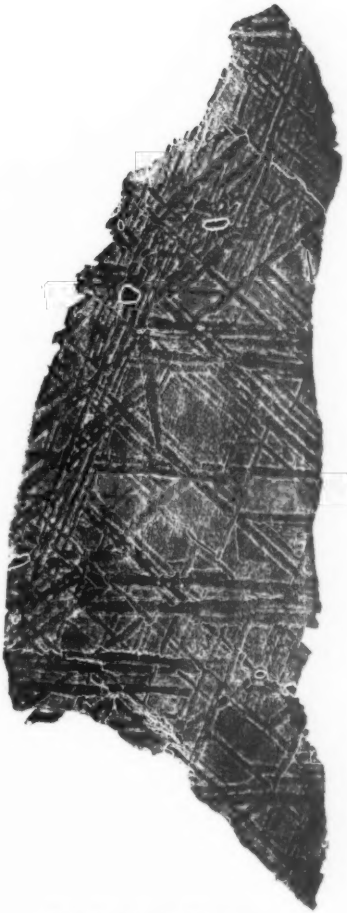
Mr. May was plowing new ground when he discovered the meteorite, only partially covered with soil. It was of a rough lense shape with one side flattened and weighed 15½ pounds. With the aid of an old axe the mass was finally separated, and the smaller part was carried away, mislaid, and apparently lost beyond recovery by a party who did not appreciate its value.

The larger portion, weighing 8½ pounds, was secured by Mr. S. W. McCallie, Assistant State Geologist of Georgia, and obtained by me in an exchange with the State Museum. This mass has evidently been materially reduced in size and weight by oxidation, leaving, however, a solid mass after the oxidized portions were removed.

The Widmanstätten figures are strongly marked and distinctive, the special feature being the large masses of plessite which are shown in Plate IV printed direct from an etched section.

The following is an analysis for which I am indebted to Mr. H. N. Stokes by the courtesy of Prof. Clarke, Chief Chemist of the U. S. Geological Survey; it shows nothing unusual in composition.

Fe	91·96
Ni	6·70
Co	0·50
Cu	0·03
Si	*tr.*
P	0·11
S	0·01
C	*tr.?*
	99·31



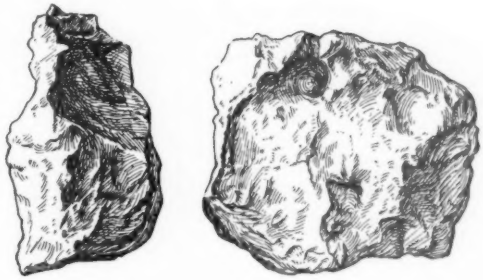
THE CHEROKEE METEORITE.

The only other meteorite to my knowledge found in that portion of the state is the "Losttown" found in 1868 and described by Shepard. This, however, was very different in appearance and composition, containing only 3·66 per cent of nickel, which alone would be sufficient to distinguish them.

2. *The El Capitan Meteorite.*

This handsome meteorite was found by a Mexican sheep herder, Julian Jesu, in July, 1893, on the northern slope of the El Capitan range of mountains in New Mexico. Three small pieces were broken from the thin edge, which show beautifully the octahedral structure of the iron. The smallest of these, weighing a few ounces, was sent to the National Museum, and the two larger, weighing respectively 1 lb. 12½ ozs. and 3 lbs. 14 ozs., together with the main mass, 55 lbs., came into my possession at different dates in 1894.

The weight of the iron when whole was about 61 lbs.; the general shape is shown in the accompanying cuts. It measured 10×9×5 inches thinning at one edge and had the usual irregular pitted surface.



My information in regard to the history of the meteorite, as well as the meteorite itself, was obtained from Mr. C. R. Biederman of Bonito, N. M. Mr. Biederman says that he, in company with many miners, was standing in front of a store in Bonito sometime in July, 1882, when "they saw a meteorite which looked like a fiery ball moving rapidly toward the north at an angle of 45° and vanish behind the Capitan range." Mr. Biederman thinks the meteorite found by the Mexican is the one they saw fall, and there is nothing in its appearance to disprove his claim. It is entirely free from oxidation and evidently fell at a comparatively recent date.

The Widmanstätten figures are developed very easily and clearly, as is usual with irons containing the percentage of nickel which this has, showing it to belong to the usual type of octahedral irons, with rather broad bands of kamacite somewhat like those in the Cooperstown meteorite.

I am indebted also to the courtesy of Prof. Clarke for the following analysis of this iron by Mr. H. N. Stokes of the U. S. Geological Survey:

Fe	90·51
Ni	8·40
Co	0·60
Cu	0·05
Si	*tr.*
P	0·24
S	*tr.*
	99·80

ART. XXVIII.—*The Reduction of the Acids of Selenium by Hydriodic Acid;* by F. A. GOOCH and W. G. REYNOLDS.

[Contributions from the Kent Chemical Laboratory of Yale College.—XLIII.]

A METHOD for the iodometric determination of selenious acid has been recently announced by Muthmann and Schaefer* which is based upon the reduction of selenious acid by hydriodic acid and the direct titration of the iodine thus liberated. To determine the selenious acid it is only necessary to add it in solution to an acidulated solution of potassium iodide, when iodine and selenium are both set free in elementary form, the former being directly determinable by titration with sodium thiosulphate after addition of starch. The difficulty in the process is said to be the uncertainty as to the exact point in the titration at which the starch blue disappears from the liquid in which the finely divided and opalescent selenium is held in suspension. For this reason the process is recommended for use only when great accuracy is not essential.

Evidently if the reaction between the acidulated iodide and selenious acid is single and complete, the process should be capable of improvement by removing the selenium before the titration is attempted. This we have succeeded in doing without difficulty. We find the most convenient and rapid way to remove the finely divided selenium is to filter the liquid con-

* Berichte d. d. chem. Gesell., xxvi, 1008.

taining it by means of the vacuum pump upon a thick felt of asbestos in a perforated crucible or cone of large filtering surface. With a properly prepared filter of this description there is no difficulty in separating the selenium in a very few moments so completely that it is possible to determine the iodide remaining dissolved in the excess of potassium iodide with all the accuracy characteristic of this most exact of titration processes. We find, however, that when the difficulty of determining the end-reaction in the titration of the iodine by the thiosulphate is overcome, it becomes apparent that the reaction upon which Muthmann and Schaefer depend is not perfect. Either the reduction of the selenious acid to selenium is not complete, or else the iodine remains in combination to a slight extent with the selenium and so fails to appear in the filtrate. This is evident from the results of the experiments of Table I, in which the selenious acid and potassium iodide acidulated with hydrochloric acid were brought together, the liquid thrown upon the asbestos filter, the selenium washed until free from soluble iodine, and the filtrate containing the iodine treated as usual with sodium thiosulphate in presence of starch. The details of treatment are described sufficiently in the table. The selenium dioxide was prepared for the work from the so-called pure elementary selenium by dissolving it in strong nitric acid, evaporating off the excess of the last, treating the solution of the residue in water with barium hydroxide, filtering to remove selenic acid formed in the oxidation and traces of sulphuric acid possibly present as an impurity, recovering the selenium dioxide by evaporation, and purifying it by subliming and re-subliming it in a current of dry air until it was clean and white.

TABLE I.

SeO_2 taken. grm.	KI used. grm.	HCl used. (Sp. gr. 1·20) cm^3	Volume before filtering. cm^3	SeO_2 found. grm.	Error. grm.
0·0499	1	5	100	0·0479	0·0020—
0·0499	1	5	100	0·0477	0·0022—
0·2035	3	5	100	0·1896	0·0139—

From these figures it is plain that iodine was not found in the filtrate in amount corresponding to the selenium dioxide present. In the following experiments of Table II. an excess of the thiosulphate was added before filtering off the selenium so that there should be every opportunity for the iodine and thiosulphate to interact before the removal of the selenium. In two experiments the proportion of hydrochloric acid was

increased tenfold for the purpose of seeing whether the presence of a large amount of free acid influences the result.

TABLE II.

SeO_2 taken. grm.	KI used. grm.	HCl used. (Sp. gr. 1·20) cm^3	Volume before filtering. cm^3	SeO_2 found. grm.	Error. grm.
0·0499	1	5	100	0·0489	0·0010—
0·0499	1	3	100	0·0485	0·0014—
0·0499	1	50	100	0·0489	0·0010—
0·0499	1	50	100	0·0488	0·0011—
0·2006	3	5	100	0·1925	0·0081—
0·2030	3	5	100	0·1945	0·0085—

These results show improvement over those obtained when filtration is made before acting with the thiosulphate, but it is obvious that the presence of a large proportion of free hydrochloric acid is without effect upon the reaction, and that the iodine set free and measured is still deficient in proportion to the amount of selenium dioxide present. Plainly the reduction of the selenium dioxide is incomplete or else there is formed between the selenium and iodine a combination, such as was noticed by Hautefeuille* in the interaction of iodine upon hydrogen selenide. In either case it should be possible to push the reaction farther toward completion by submitting the mixture of selenious acid, potassium iodide, and hydrochloric acid to distillation. We have used for this purpose an apparatus employed and described in connection with previous similar work in this laboratory. The distillation flask is a Voit gas-washing flask, and this is sealed to the inlet tube of a Drexel wash-bottle used as a receiver, to the outlet tube of which is sealed a Will and Varrentrapp absorbtion apparatus to serve as a trap. The mixture to be distilled was introduced into the flask, a solution of 3 grm. of potassium iodide in 100 cm^3 of water was put into the receiver and trap and during the distillation a slow current of carbon dioxide was passed through the apparatus to keep the boiling regular. Naturally the acidified solution of the iodide in the flask retains with great tenacity traces of dissolved iodine, so that, in order to determine all the iodine liberated in the reaction, the residue in the flask as well as the distillate in the receiver and trap was titrated in the usual way with sodium thiosulphate. The details of treatment and the results are recorded in Table III.

* Compt. Rend., lxviii, 1554.

TABLE III.

SeO_2 taken. grm.	KI in flask. grm.	HCl in flask. (Sp. gr. 1·20) cm^3	Total volume boiled. cm^3	Time in minutes.	SeO_2 found. grm.	Error. grm.
0·0499	1	5	60	5	0·0497	0·0002 —
0·0499	1	5	60	5	0·0497	0·0002 —
0·0499	1	5	60	10	0·0496	0·0003 —
0·2000	3	5	60	10	0·1995	0·0005 —
0·2000	3	5	60	10	0·1991	0·0009 —
0·2023	3	5	60	10	0·2018	0·0005 —
0·5018	3	5	60	10	0·4635	0·0383 —

These results are all fairly good, though all a little deficient, for amounts of selenium dioxide up to 0·2 grm; but when the amount of the dioxide reaches 0·5 grm. the iodine found in the distillate and in solution in the residue falls far below the theory based upon the assumption that the products are selenium, iodine, and water. The selenium in the residue was left after the boiling in fine dense crystalline condition in the experiments with the smaller amounts, so that it did not interfere with the titration of the free iodine; but in the last experiment, in which approximately 0·5 gram. of the dioxide was treated, the selenium remained in pasty form adhering to the flask. Subsequent examination proved that the pasty selenium held iodine, which was liberated slowly to water and more rapidly to an aqueous solution of potassium iodide. The largest errors have been found (excepting that of the last experiment from the discussion) when the free iodine was filtered off from the reduced selenium; better results were obtained when the precipitated selenium was first treated with the thiosulphate before filtering; and in the distillation process the best approximations are made to true indications. It is obvious that as the proportion of selenium and iodine increase, the tendency to form a combination is more manifest. The error thus introduced in the determination of the selenium dioxide by the distillation process is allowable up to the limit of 0·2 grm.

Potassium iodide in hydrochloric acid acts much less readily upon selenic acid than upon selenious acid. When the hydrochloric acid is present in small proportions in the mixture of selenic acid and the iodide the reduction is very imperfect, but it tends to approach completion as the strength of hydrochloric acid is increased.

It is obvious, in the light of the previous experiments with selenious acid, that it is unreasonable to expect the full liberation of iodine in the action of selenic acid upon the iodine

when the free iodine is not removed from the sphere of action as it is liberated. In the distillation process the case is otherwise, and there is no reason to anticipate that the determination of selenic acid should present greater difficulty than is encountered in treating selenious acid under similar circumstances. The experiments of Table IV, in which selenic acid (obtained by oxidizing known amounts of selenium dioxide by means of potassium permanganate in the manner described in a previous paper from this laboratory)* is treated according to the distillation method outlined above for the determination of selenious acid, show that this expectation is realized, and that the analytical results are fairly good.

TABLE IV.

SeO_2 taken. grm.	KI in flask. grm.	HCl in flask. (Sp. gr. 1·20) cm^3	Total volume boiled. cm^3	Time in minutes.	SeO_2 found. grm.	Error. grm.
0·0593	1	5	60	5	0·0593	0·0000
0·0593	1	5	60	5	0·0591	0·0002 −
0·0593	3	5	60	10	0·0596	0·0003 +
0·1779	3	5	60	10	0·1769	0·0010 −
0·1779	3	5	60	10	0·1780	0·0001 +
0·1779	3	5	60	10	0·1764	0·0015 −

In conclusion, it is plain that while the simple contact of solutions of selenious acid or selenic acid and potassium iodide acidified with hydrochloric acid does not determine the liberation of the full amount of iodine which would be expected if selenium, iodine and water were the sole products of action, it is possible to bring about such action with a close approximation to completeness, when the amounts of selenium present are not too large, by submitting such mixtures to distillation. We prefer, in applying the reaction to analytical purposes, to work with the apparatus and under the conditions described—treating, preferably, not more than 0·2 grm. of the selenium oxide, using from 1 grm. to 3 grm. of potassium iodide in the distilling-flask with 5 cm^3 of strong hydrochloric acid in a total volume of 60 cm^3 and continuing to boil for ten minutes.

* Gooch and Clemens, this Journal, 1, 51.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Helium, a constituent of certain Minerals.*—In a paper by W. Ramsay, J. Norman Collie and M. Travers, read before the Chemical Society on June 20, the results are given of an extended series of experiments upon the gas yielded by cleveite and allied minerals, to which the name of helium was given by Ramsay in the first account of its discovery a few months since, as already noted in these pages. This name was based upon the fact that the spectrum of the gas in question is characterized by a yellow line, which is very nearly, if not quite, coincident (see remarks on p. 261) with the line D_3 in the solar spectrum (wave length 5875·982 Rowland). It will be remembered that some thirty years since Lockyer and Frankland gave the name helium to the hypothetical solar element corresponding to the absorption line D_3.

The authors recall the fact at the outset that Palmieri states that a yellow spectral line with wave length 587·5 was obtained by him from a soft substance occurring as a lava-like product ejected by Vesuvius. They also allude to the investigations of Hillebrand on the various kinds of uraninite and the gases occluded by them which he regarded as nitrogen, and show that they actually contain 10 p. c. by volume of this gas, enough to explain the confirmatory chemical experiments showing the presence of nitrogen as also the strong nitrogen spectrum—for the spectrum of helium is masked by a comparatively small amount of nitrogen. It is added that if Hillebrand had operated with cleveite he would in all probability have discovered helium.

A large number of minerals have now been tested, 2 to 5 grams of the coarsely powdered substance in each case being heated to redness in a small bulb of combustion-tubing, previously exhausted by a Töpler pump. The details as to manipulation and the analytic processes applied to remove gases evolved with the helium (hydrogen, etc.) cannot be described here. The following species yielded helium and in most cases hydrogen also: Yttrotantalite, samarskite, hjelmite, fergusonite, tantalite, pitchblende, polycrase, all containing uranium; also, monazite, xenotime, orangeite. Negative results were obtained from a number of other minerals, including columbite, perofskite, thorite, allanite, gadolinite and others.

After briefly considering the composition of the minerals named with a view to deciding as to what constituent is effective in retaining helium, the authors remark: "From these details, it may be concluded that the helium is retained by minerals consisting of salts of uranium, yttrium, and thorium. Whether its presence is conditioned by the uranium, the yttrium or the thorium, we are hardly yet in a position to decide. To judge by the Cor-

nish ore [pitchblende], oxide of uranium alone is sufficient to retain it; but that its presence is not absolutely necessary is shown by its existence in monazite and xenotime. The high atomic weights of uranium and thorium and the low atomic weight of helium suggest some connection; and yet yttrium, which possesses a medium atomic weight, sometimes appears to favor the presence of the gas; for yttrium is present in yttrotantalite, which, however, contains uranium, and in cleveite, in which uranium is present in relatively large amount.

Of the minerals experimented upon, the only ones which may be taken as a source of helium are cleveite, the uraninite investigated by Hillebrand (Glastonbury, Conn.) and bröggerite. Samarskite and yttrotantalite might be added to these, but large quantities of these species would have to be worked up.

In order to fix the *density* of helium a number of separate determinations were made upon the gas liberated from bröggerite and cleveite. The final results are as follows:

Gas from bröggerite by heating	2·152
Gas from bröggerite with $HKSO_4$	2·187
Gas from cleveite	2·205
Mean density	2·181

The *ratio* of the two *specific heats* was also determined by the method depending upon the velocity of sound in the gas and the value obtained was:

1·652

This is very near the theoretical value 1·66. The purest sample of argon gave 1·659. It follows that helium has "the same claim to be considered a monatomic gas as mercury gas; or if it is a mixture, it must be a mixture of monatomic gases."

The *solubility* of helium was determined by the same method employed for argon and the result obtained is

1 vol. water absorbs 0·0073 volume helium.

This is the lowest solubility hitherto recorded. The authors, noting the fact that the solubility of a gas is in general related to the temperature at which it condenses to a liquid, remark that the low solubility of helium points to a very low boiling point, as low or perhaps lower than that of hydrogen. Experiments on the temperature of liquefaction are promised by Prof. Olszewski. It is added that helium is totally insoluble in absolute alcohol and benzene.

The following remarks upon the spectrum of helium, and finally the conclusions to which the work as thus far carried out have led, are here quoted in full:—

The Spectrum of Helium.—Mr. Crookes is making an exhaustive study of the spectrum of helium, and will shortly publish an account of his work. But, as some of the deductions to be drawn later depend on the lines observed, it is necessary here to

add a few words. In general terms, the spectrum has already been described. The particular point to which attention is necessary here is that at least two of the lines in the spectrum of helium, seen with a wide dispersion prism, are coincident with two of the argon lines. These occur in the red, and comprise one of each of the two pairs of characteristic argon lines. This observation has been frequently repeated, using for the purpose spectroscopes of different dispersive power, and throwing into the field both spectra at the same time, with an exceedingly narrow slit; and we may say that if not absolutely identical, the lines are so near that it is not possible with the means at our disposal to recognise any difference in position. But the relative brilliancy is by no means the same. One of the argon lines, rather faint, is coincident with the prominent red of the helium spectrum, and one of the strong red argon lines is coincident with a faint red line in the helium spectrum.

Besides these two, there is a line in the orange-red, which though perhaps not identical, yet is very close. This line is faint in helium, but moderately strong in argon. It is much more easily visible with helium in the "negative glow" than in the capillary tube.

It may also be of interest to state that, according to Runge's observation, the brilliant yellow line of helium is undoubtedly a doublet. This was frequently observed by us with a grating of 14,000 lines to the inch in the spectrum of the third order. But it must also be noted that one of the lines is very faint; the other, more refrangible, is immensely brighter. The distance, judged by eye, appears to be about $\frac{1}{50}$th part of that between the lines D_1 and D_2 of sodium. Accurate information on this last point may be looked for from Mr. Crookes, Mr. Lockyer, and from many others who are interested in the probable occurrence of this element in the sun.*

General Conclusions.—It cannot be doubted that a close analogy exists between argon and helium. Both resist sparking with oxygen in presence of caustic soda; both are unattacked by red-hot magnesium; and if we draw the usual inference from the ratio between their specific heats at constant volume and at constant pressure, both are monatomic gases. These properties undoubtedly place them in the same chemical class, and differentiate them from all known elements.

Although opinion is divided on the precise significance of the ratio of specific heats, 1·66, it appears to be most probable that in all cases, as in that of mercury, this ratio points to the monatomicity of the molecule. If we assume this provisionally, it follows that the atomic weight of helium is identical with its molecular weight. The molecular weight is twice the density, for the molecular weights of gases are compared with the atomic weight of hydrogen, taken as unity; hence the atomic weight of

* Prof. Hale and Dr. Huggins have recently observed that the solar line D_3 is also a doublet. (W. R., July 20.)

helium on this assumption is $2{\cdot}13 \times 2 = 4{\cdot}26$. But again we assume, in making this calculation, that helium is a single element, and not a mixture of elements. Before discussing this question, it appears advisable to inquire whether there is any evidence which would corroborate the deduction that it is a monatomic element. This evidence must be sought for in the properties of argon, for those of helium have not as yet been sufficiently investigated.

We know from countless examples among compounds of hydrogen and carbon that increase in molecular weight is accompanied by rise of boiling point; and it may be stated as a proved fact that a polymeride has always a higher boiling point than the simpler molecule of which the polymeride is formed. Among the substances germain to this inquiry, ozone and oxygen may be cited; the complex molecule of ozone is shown by the higher temperature at which it boils. It might be concluded with certainty, therefore, that A_2, could it exist, should have a higher boiling point than A_1.

Next, it is generally the case that the boiling point of an element, provided it has not a complex molecule like that of sulphur and phosphorus, is lower, the lower its molecular weight. There are the well-known instances of chlorine, bromine, and iodine; but if it be objected that these all belong to the same group, we may cite the cases of hydrogen, $-243{\cdot}5°$; nitrogen, $-194{\cdot}4°$; and oxygen, $-182{\cdot}7°$; and we may add chlorine, $-102°$. If argon possessed the atomic weight 20 and the molecular weight 40, it is probable that its boiling point would lie above that of chlorine, instead of, as is actually the fact, at $-187°$—below that of oxygen. But, it may be objected, the boiling point is determined, not by the molecular weight, but by the density. It may be urged that the density of argon is 20, and that its molecules, like those of oxygen and nitrogen, are diatomic, in spite of the argument to the contrary from the ratio of specific heats. The answer to this objection is obvious; if this were so, its boiling point should lie above, and not below that of oxygen.

These considerations cannot, of course, be accepted as evidence, but merely as corroborative of the conclusion as regards the monatomicity of argon. If they apply to argon, they apply with equal force to helium; and if they are accepted, it follows that the atomic weight of helium is 4·26.

It is again necessary to consider the character of argon in attempting to answer the next question: Are argon and helium single elements or mixtures of elements? But before discussing it, let us consider another question: How does argon happen to occur in the air and helium only in minerals? Why is helium not present in air? A satisfactory answer to the question is, we think, contained in a paper by Dr. Johnstone Stoney (Chem. News, 1895, lxxi, 67). He there shows that were hydrogen to be present in air (and it might be present, in spite of the oxygen with which it could be mixed, for a small quantity would surely

escape combination), it would, in virtue of the velocity of its own proper molecular motion, remove itself from our planet, and emigrate to a celestial body possessing sufficient gravitational attraction to hold it fast. Dr. Stoney suggests this explanation to account for the absence of an atmosphere and of water vapour on the moon, and for the presence of an atmosphere of hydrogen on the sun. It would also account for the absence of helium in our atmosphere, and for the presence of the chromospheric line D_3. Of course if an element can form compounds, or if it is absorbed by solids, as helium appears to be, it will, like hydrogen and helium, be found on the earth.

The inertness of these gases would favor their existence in the free state. And argon exists in the atmosphere, precisely because it forms no compounds. Similarly nitrogen is a constituent of air, because in the first place those elements with which it combines directly are comparatively rare, and also because such compounds are mostly decomposed by water; and the excess of nitrogen therefore occurs in the free state. Similarly, the occurrence of free oxygen is due to the fact that some remains over, after all or almost all the readily oxidized substances have already united with oxygen. If there exist gases similar to argon in inertness, they two may be looked for in air.

Now if argon possesses the atomic weight 40, there is no place for it in the periodic table of the elements. And up to now there is no exception to this orderly arrangement, if the doubtful case of tellurium be excluded. Rayleigh and Ramsay have shown that the high density of argon can hardly be accounted for by supposing that molecules of A_2 are mixed with molecules of A_1; and excluding as untenable the supposition that argon is a compound, the only remaining suggestion is that it is a mixture. No attempts have as yet been made to test the correctness of this idea; but experiments have already been started which, it is hoped, will throw light on this question.

The density of argon is too high; to fill its place in the periodic table, between chlorine and potassium, its density should be about 19 and its atomic weight 38. We might expect the presence of another element with a density of 41 and an atomic weight of 82, to follow bromine, as argon follows chlorine; and this element would probably also be a gas, since its density would be only a little higher than that of chlorine.

But here we meet with a difficulty. There are certain lines in the spectrum of helium coincident with lines in the argon spectrum. There can be only one explanation, excluding the extremely improbable hypothesis, which is not verified in any instance, that two elements may give spectra containing identical lines. That explanation is, of course, that each contains some common ingredient; and there appears to be a place for one with density 10 and atomic weight 20, to follow fluorine in the periodic table. The density of helium is, however, so low, that there does not appear room for any large quantity of a heavier gas; and to fit the periodic table, the density of argon should be

diminished by removal of a heavier admixture, rather than increased by removal of a lighter one.

Such are the problems which now confront us. Until more experiments have thrown further light on the subject, we regard it as labor lost to discuss the relations of these curious elements to others which find their proper place in the periodic table.—*Nature*, July 25, Aug. 1.

2. *Argon and Helium in Meteoric Iron.*—Professor W. Ramsay, extending his researches upon the new element argon, has proved that it exists with helium in meteoric iron. The meteorite investigated was that of Augusta county, Virginia, two ounces of which, heated to redness in a hard glass tube, yielded 45 c.c. of gas. This appeared to consist chiefly of hydrogen, but after it had been exploded with oxygen, and the carbon dioxide and excess of oxygen absorbed, a residue of half a cubic centimeter was obtained. Several vacuum tubes having been filled with this after being dried, spectroscopic examination proved it to be for the most part *argon*, the trace of nitrogen which first appeared rapidly disappearing. All the argon lines were observed and also, faintly, the yellow D_3 of helium. A comparison of the spectrum with that of the helium from cleveite showed the presence of the red, blue-green, blue and violet lines characteristic of it. From quantitative observations with a mixture of argon and helium it is concluded that the latter element makes up less than 10 p. c. of the gases obtained from the meteoric iron. *Nature*, lii, 224.

3. *The physical properties of Argon.*—Lord Rayleigh gives the following determination of the density of argon ($O_2 = 16$):

19·940

This result was obtained with the gas prepared from atmospheric air with the aid of oxygen and alkali only, and employing large quantities (two liters at 0°). It agrees almost exactly with the determination of Professor Ramsay made upon a relatively small amount and with gas derived from magnesium. In spite of its greater density the refraction ($\mu - 1$) of argon is only 0·961 of that of air. Hence if for air under standard conditions, $\mu = 1{\cdot}0002923$, we have for argon

$$\mu = 1{\cdot}000281.$$

—*Nature*, lii, 293.

4. *The Fluorescence of Argon.*—M. Berthelot has carried on, in conjunction with M. Deslandres, a series of careful experiments on the fluorescence of argon which accompanies its combination with benzene under the influence of the silent discharge; this it appears is accomplished with the help of mercury in the form of a volatile compound. The effect at first is feeble and only to be observed in a dark room, but after some fifteen hours a brilliant emerald fluorescence is obtained, visible in broad daylight and indeed more intense than that given by any other known gas. The wave lengths of the lines given in the photographs are: 579, 577 and 546; 436, 405, 313, 312 (ultra-violet); also two violet lines besides, 420 and 416, scarcely visible, and

further 385 and 358. Most of these lines coincide very closely with the determination of Crookes of the lines of rarefied argon; 313, 312, however, are mercury lines. It is also noted that certain of the lines observed by Crookes coincide with those of mercury vapor and the same coincidence is noted in the lines visible in daylight under normal pressure in the fluorescence developed during the reaction of benzene on argon. These lines develop themselves only after several hours with the argon saturated with benzene and seem to be due to one of the condensed compounds from the benzene uniting itself with the argon and mercury.—*Comptes Rendus*, June 24; *Nature*, lii, 255.

5. *The Principles of Physics*, by ALFRED P. GAGE, Ph.D. 634 pp. Boston and London 1895 (Ginn & Company).—Those who are acquainted with the excellent features of Gage's *Elements of Physics* (1882) will expect to find the present volume, prepared to fill a somewhat different place, a desirable addition to our elementary text-books, and in this they will not be disappointed. It presents the principles of the subject from the didactic not from the experimental side, and it does so clearly and simply, with numerous fresh illustrations. The shortcomings of such a volume are those inevitably incident to the attempt to compress a subject of so vast extent into the limits of a small volume; the author has made, however, good use of the space which has been allowed him.

II. GEOLOGY AND MINERALOGY.

1. *The Protolenus fauna;* by G. F. MATTHEW. (Trans. N. Y. Acad. Sci., vol. xiv, pp. 101–153, Plates I–XI, March 17, 1895.)—This interesting early Cambrian fauna, some species of which have been described before,* has been increased to the number of seventy species, which were chiefly obtained from the section in Hanford Brook, St. John, New Brunswick, by Messrs. Gilbert Van Ingen and W. D. Mathews of the Geological Department of Columbia College and the author. The stratigraphical relations of the fauna may be described most concisely by reproducing the table of life zones of the St. John Group, the details of which are fully elaborated by the author in the Transactions of the Royal Society of Canada.

In descending order they are as follows:

St. John Group.	Division 3 Bretonian.	Band *d*	Fauna of	*Tetragraptus quadribranchiatus.*	
		" *c*	" "	*Dictyonema flabelliformis.*	
		" *b*	" "	*Peltura scarabeoides.*	
		" *a*	" "	*Parabolina spinulosa.*	
	Division 2 Johannian.	" *c*	" "	*Lingulella radula.*	Place of the Olenus Fauna.
		" *b*	" "	*L. —— Starri.*	
		" *a*	" "	----------	
	Division 1. Acadian.	" *d*	" "	*Paradoxides Abenacus cf. Tessini.*	
		" c^2	" "	*P. —— Etiminicus cf. rugulosus.*	
		" c^1	" "	*P. —— lamellatus cf. œlandicus.*	
		" *b*	" "	PROTOLENUS (found in b^2 and b^3).	
		" *a*	No fauna known.		

* Trans. Roy. Soc. Can., vol. vii, sec. iv, p. 135; vol. xi, sec. iv, p. 85. Nat. Hist. Soc. N. Brunswick, Bull. 10, p. 34.

The mass of sediments which directly underlie this St. John Group, including the conglomerates called Etcheminian by the author, are now regarded by him to be actually Pre-Cambrian.

This fauna, therefore, appears to be the oldest of which we have any elaborate knowledge, although it should be noted that the Olenellus fauna has not been discovered in this section, and the fauna immediately succeeding the Protolenus fauna in the Hanford Brook section is the Paradoxides fauna.

The fauna is thoroughly primordial in character: there are two genera of Foraminifera (*Orbulina* and *Globigerina*). There are three genera of Spongida (*Monadites*, *Protospongia* and *Astrocladia?*). The Brachiopoda are represented by *Lingulella*, *Obolus*, *Trematobolus*, *Obolella*, *Linnarssonia*, *Acrotreta*, *Acrothele*, and a specimen referred to as an Orthid. Among the forms referred to *Obolus* are some which differ slightly from the typical genus and are described under the subgenus *Botsfordia*. The author has been able to make out several stages of development for *B. pulchra*, which he summarizes as follows: "This species, then, is marked by four stages of growth and development, of which the most prominent features are the following :—

(1.) *Embryonic.*—Formation of the embryonic shell.

(2.) *Larval or nœpionic.*—Lengthening of the hinge line and acquisition of mantle-margins.

(3.) *Adolescent or nealogic.*—Fixation of the hinge line, otherwise as the last, except that the radular ornament becomes irregular.

(4.) *Adult or ephebolic.*—Absence of radular ornamentation on the valve, and great expansion of the mantle-margin." The genus *Trematobolus* is remarkable as combining the unmistakable characteristics of the inarticulate order of Brachiopods, yet having a distinct articulation of the hinge line. The mollusca are represented by *Hyolithellus*, *Coleoides*, *Orthotheca*, *Hyolithes*, *Diplotheca*, a peculiar new genus, *Pelagiella*, which appears to have been a free swimmer and to belong to the Heteropoda, and *Volborthella*. In this group the Hyolithidæ are prominent, and all of the mollusca seem to have been of pelagic type. Nearly half of the species described are Arthropoda. Among the Ostracoda are *Hipponicharion*, *Beyrichona*, *Aparchites*, *Primitia*, *Schmidtella* and *Leperditia*. The new genus *Beyrichona* was originally described in the Transactions* of the Royal Society of Canada, and the author, upon study of better material, has modified the description by reversing the anterior and posterior portions of the shell. The two species referred to *Aristozoa* by Walcott, Mr. Matthew considers to be species of this genus. One supposed Phyllopoda (*Lepiditta*) is described. Of Trilobites, thirteen species are described, and referred to the genera *Protograulos*, *Ellipsocephalus*, *Micmacca*, *Avalonia*, *Protolenus* and *Bergeronia*.

As salient features separating this fauna from all others, the author mentions the following points: All the trilobites have

* Vol. iii, p. 65.

continuous eyelobes; the important family of the Ptychoparida is absent; the genera *Conocoryphe*, *Microdiscus* and *Olenellus* are absent. He further remarks: "This fauna is distinguished from that of *Olenellus* by two marked features. It is more *primitive* and also more *pelagic*. The way in which the trilobites are bound together by a single feature of a continuous eyelobe shows a unity of origin and a closer relationship than is found in the trilobites of any other fauna, and yet among these trilobites there are forms which in other respects are parallel to the types which developed in the later faunas. Thus in *Protolenus* we have the flat pleura, with the diagonal furrow of *Paradoxides*, but in subgen. *Bergeronia* the deeply-grooved, geniculated pleura of *Ptychoparia*, and at the same time the prominent glabella and deep dorsal furrows of *Solenopleura*. *Micmacca*, as has already been said, predicates *Zacanthoides* of a later fauna. Finally, *Protograulos*, in its almost obliterated glabella and flat cephalic shield, recalls *Agraulos* and *Holocephalina* of the Paradoxides fauna. It is a more *pelagic* fauna than that of *Olenellus*, for we notice the absence of many forms of the *Olenellus* fauna that were differentiated for shore-conditions. Trilobites with fixed outer checks, like *Olenellus* and *Microdiscus*, are absent; calcareous corals and sponges are rare, and no Lamellibranch is known. On the other hand, Foraminifera are quite common in some layers, and the Gasteropods are mostly such as were adapted for comparatively deep water."

Although the evidence is not conclusive that the fauna lived before the Olenellus fauna, it is without doubt a different fauna. The two faunas may have been contemporaneous, the author observes, the Protolenus fauna being adapted to deeper and quieter waters than the other. In this case "we would expect," he writes, "that at a locality where the two faunas occurred in succession in a series of deposits, the Olenellus fauna would be found beneath that of Protolenus," and he expresses the opinion that assises 4 and 5 (of the Hanford brook section) [this fauna occurring chiefly in assises 2 and 3] show no trilobite fauna and "this seems the more probable place for the Olenellus fauna, seeing that while this fauna has several genera of trilobites in common with the Paradoxides fauna, it has but two that are found in the Protolenus fauna." H. S. W.

2. *Pre-Cambrian organisms.*—L. Cayeux has recently published* a preliminary note on the existence of numerous remains of Sponges in the pre-Cambrian schists of Brittany, thus adding to the known organisms of this early fauna.† The evidence is in the form of pyritized sponge spicules of which the original form

* "De l'existence de nombreux débris de Spongiaires dans le Précambrian de Bretagne," par L. Cayeux; Ann. Soc. Géol. du Nord., vol. xxiii, 1895, pp. 52–64, June, 1895.

† "Sur la présence de restes de Foraminifères dans les terrains précambriens de Bretagne. C. R. Ac. Sc., t. cxviii, pp. 1433–1435 et Ann. Soc. Géol. du Nord, vol. xxii, pp. 116–119. See also Bull. Soc. Géol., Fr., 3e Série, t. xxii, pp. 197–228, pl. xi (1894).

is preserved, and the author has determined species referable to each of the four orders of siliceous sponges, viz: Monactinellidæ, Tetractinellidæ, Lithistidæ and Hexactinelledæ.

The geological horizon from which the fossils came is the "phtanites de Lamballe" in the Phyllades de Saint-Lô of Barrois, near Lamballe, Brittany. The Radiolarians, previously described by the same author, were obtained from the same formation. The specimens in both cases were discovered by M. Ch. Barrois. The author infers, from the evidence of breaking and wearing of the spicules before they were pyritized, that there were strong marine currents in the waters when the deposits were found, and therefore that the depth was not great during the deposition of the phtanites. H. S. W.

3. *Grundzüge der Palæontologie* (*Palæozoölogie*) von Karl A. von Zittel, pp. i–viii and 1–971 and 2048 figures, 1895.—This is more than a condensation of the "Handbuch" which has taken such a well deserved first place among treatises on Paleontology. The great progress in systematic zoölogy since the "Handbuch" was begun in 1876, is expressed in a thorough revision of the classification, particularly of the Invertebrates. As these changes are of much importance to all who use the book, the chief of them are here noted.

Eight branches are recognized in the animal kingdom. The Vermes are given a separate place, and the Molluscoidea are separated from the Mollusca, as most zoölogists have done for the past twenty years. The Tunicates are not considered.

In the branch Protozoa, Monera are no longer recognized and the fossil forms are distributed in the two orders *Foraminifera* and *Radiolaria* of the class Rhizopoda.

The Coelenterata are separated into the three sub-branches *Porifera*, including the class Spongia, and *Cnidaria*, with the two classes Anthozoa and Hydrozoa, and *Ctenophora;* no fossil remains of the latter being reported. The four orders of Sponges which have a more or less siliceous framework are grouped together as *Silicispongiæ*.

The class Anthozoa is entirely rearranged: Haeckel's three sub-classes, *Tetracorallia*, *Hexacorallia* and *Octocorallia* are recognized. Madreporaria is subdivided into the three sub-orders of Edwards and Haime,—*Aporosa*, *Perforata* and, as an appendix, *Tabulata*, in which latter group are included the *Favositidæ* and associated forms, and the *Chætetidæ*, which in the "Handbuch" were distributed with the Bryozoa.

Haeckel's three sub-branches of the Echinodermata are adopted, viz: *Pelmatozoa* (Crinoidea, Cystoidea and Blastoidea), *Asterozoa* (Ophiuroidea and Asteroidea) and *Echinozoa* (Echinoidea and Holothurioidea).

Following the Wachsmuth and Springer classification, the Crinoids are distributed in the three orders *Larviformia*, *Camarata* and *Fistulata*. The Molluscoidea are recognized as a distinct branch. The subdivisions of the Bryozoa are left substan-

tially as in the older work. In the Brachiopoda the only important change is in adopting the grouping of the Articulata suggested by Waagen, though with some change in the names, viz: *Aphaneropegmata*, *Helicopegmata*, *Ancistropegmata* (=Campylopegmata p. p. Waagen) and *Ancylopegmata* (=Ancylobranchia Gray, Campylopegmata p. p. Waagen).

The Mollusca are distributed in the five classes, *Lamellibranchiata*, *Scaphopoda*, *Amphineura* (adopted from Ihering), *Gastropoda* and *Cephalopoda*. Neumayr's natural separation of the *Anisomyaria* from the *Homomyaria* is recognized in the classification of the Lamellibranchiata; also his classification of the latter order into the sub-orders *Toxodonta*, *Pachyodonta*, *Heterodonta* and *Desmodonta*.

Fischer's division of the Nautiloidea and Ammonoidea respectively into Retrosiphonata and Siphonata is discarded. *Bathmoceras* is placed in the family Orthoceratidæ, and *Nothoceras* in the family Nautilidæ. The position of the siphon is made of prime importance in the Ammonoids, viz: A. the *Intrasiphonata*, with the single family Clymeniidæ, being separated from B. the *Extrasiphonata*, which includes the other families of the sub-order.

The three sub-orders *Belemnoidea*, *Sepiodea* and *Octopoda* are recognized in the Dibranchia.

The important modification of the breathing apparatus in the Arthropoda is made of sub-branch rank, thus separating the *Branchiata*, with the single class Crustacea, from the *Tracheata*, with the three classes Myriapoda, Arachnoidea and Insecta; the old divisions, *Entomostraca*, *Malacostraca* and *Merostomata* being retained as of sub-class rank.

As a result of the great differentiation discovered by Brongniart in the Carboniferous Insects of Commentry, Scudder's grouping of the Paleozoic Insects into Palæodictyoptera is discarded, and all the fossil Insects are distributed in the recognized existing orders, the *Aptera* being raised to ordinal rank.

Very few changes are made in the classification of the Vertebrates, the two volumes of the "Handbuch" on this branch having been more recently written. We, however, note the elevation of the *Leptocardii*, and the *Cyclostomi* to class rank, of which no fossil remains are reported, and the *Placodermi* to the rank of a sub-class, separating it from the Ganoids and placing it between the Selachii and the Dipnoi. Among the Mammals, the *Allotheria* of Marsh is reduced from ordinal to sub-ordinal rank, and the families of the Marsupialia are distributed in the three sub-orders *Allotheria*, *Diprotodontia* and *Polyprotodontia*. In the class Placentalia, Ameghino's *Litopterna* and Cope's *Ancylopoda*, the genera of which were previously considered in the sub-order Perissodactylia, are given the rank of distinct sub-orders in the order Ungulata.

The book is fully illustrated; each of the important groups is opened with a general description of structure and parts, and

closed with a concise summary of the geological range of the families and genera.

The more important genera are concisely described, and a large number of less prominent genera are named in their proper places with their geological position. The German edition, which has already appeared, is to be followed soon, it is announced, by an edition in English. H. S. W.

4. *The occurrence of Tertiary clay on Long Island, N. Y.*; by ARTHUR M. EDWARDS, M.D., Newark, N. J. (Communicated.) I wish to record the finding of Tertiary clay at Rockaway, Long Island, N. Y. Tertiary rock or at least clay was expected to be found on the Atlantic shore of Long Island. It was searched for on Staten Island without results. The clay found was white, at Arrochar, and was identified as Cretaceous by the shells in it. But the Tertiary above that was looked for in vain, although it may be found there. But on Sunday, 11th of August, 1895, I visited Rockaway to study the geology. I saw the moraine of the glacial period strongly marked in three hills just beyond Brooklyn Hills station; on the top and overlying the glacial drift was a coating of glacial clay having fresh-water Bacillariaceæ (Diatomaceæ) in it, the same as I found in New Jersey. The hills ended here and the rest was flat until beyond Aqueduct station. No opening was made, but I think that Cretaceous clay is under the glacial drift. At Aqueduct station the salt water begins and the cars run out on tressel works to Rockaway, where is a sandy bar. At one place, where they have been digging a ditch and recovering the land from the sea, on the opposite side of Rockaway to the Atlantic Ocean, some of the soil has been dug up. On the top is the Bacillarian clay, the Champlain glacial clay. Below this is the white glacial clay containing fresh-water Bacillariaceæ, and below this is a dark, coarse clay which I took home and examined. It is Tertiary clay having marine Bacillariaceæ. But I should think it is Upper Miocene. Lower Miocene and Oligocene are as a rule lighter in color. But the shells in it are the same. I wish to record this finding now, as it is important.

Newark, N. J., August 8.

5. *On Composite Dikes in Arran.*—Professor JUDD has described in the Quarterly Journal of the Geological Society (vol. xlix, p. 536) a series of remarkable dikes in the Island of Arran, which are excellent examples of the "composite" type, already recognized elsewhere as in Canada and Norway, described by Lawson and Vogt respectively. Unlike these last, however, in which the differentiation has gone on within the dike itself, the Arran dikes belong to a different class, formed by the injection of different material into the same fissure. It should be mentioned that these dikes are part of the latest ejections of igneous material in the British Isles. One of the dikes, that of Cir Mhor, having a total breadth between the enclosing granite walls of twenty-four feet, shows two exterior brands of augite-andesite (55·8 p. c. SiO_2), four feet wide; within these is the dike proper consisting

of two bands of quartz-felsite (75·3 p. c. SiO_2), six feet wide, enclosing in the center a band four feet in width of pitchstone porphyry (72·4 SiO_2). Another dike, one of a series at Tormore, twelve feet in thickness and extending as a sheet for a long distance, consists of the following bands in order between walls of sandstone: augite-andesite, banded and spherulitic felsite (andesite), pitchstone, felsite (as before). Still another dike of the latter region shows a band of the pitchstone-porphyry cutting obliquely across both the bands of exterior augite-andesite and the quartz-felsite within it.

After giving a detailed account of the structure and composition, mineralogical and chemical, of these dikes, the author concludes with the following summary:

"Any suggestion concerning the possible *accidental* association of the augite-andesite and 'pitchstone' in the Cir Mhor dyke is at once negatived by the study of the remarkable plexus of dykes at Tormore. No one can doubt, after the study of this latter case, that there is a real and not merely an accidental connection between the ejection of materials of such very different composition and character: all the facts, indeed, point to the conclusion that the fissures were injected from the same subterranean reservoir, but that this reservoir contained two magmas of totally different chemical composition. In the same way, as is well known, a single volcanic vent may give rise at successive periods to two totally distinct kinds of lava.

"Nor can there be any difficulty in understanding how the same fissure, while still in connection with a reservoir of liquefied lava, may be reopened and re-injected at successive periods. The plane of weakness, along which the reopening of the dyke is effected, is sometimes, as in the Cir Mhor dyke, in its center; in other cases, as in the great north-and-south dyke of Tormore, and also in the most southerly of the transverse dykes of the same district, planes of weakness are found along one or both of the lateral walls of the dyke, and it is here that the re-injection is effected; in yet other cases, also illustrated at Tormore, the new fracture seems to be quite irregular in position and to traverse the old dyke-material in a sinuous line. In one instance we have evidence of three separate injections into the same fissure.

"In some cases the more acid rock (quartz-felsite and pitchstone) was the first ejected; but, quite as frequently, the basic material (augite-andesite) was the earliest to be intruded into the opening fissure. The relative ages of the two rocks in the dyke are shown, not only by the positions which they occupy, but by the circumstance that derived minerals from the older rock are found included in the younger one. That a very considerable interval of time must have elapsed between the two injections is shown by the fact that complete consolidation and crystallization of the materials of the one rock must have occurred before its invasion by the other rock: this is proved by the characters of the junctions and also by the derived crystals.

* * * * * *

"We may classify the explanations which have been suggested to account for the differentiation of lavas into two groups:—those which rely upon some process of selective crystallization, and those which premise some kind of separation taking place in a liquid magma prior to the commencement of crystallization and consolidation.

"Differentiation during crystallization has been referred to two distinct causes. Prof. Vogt, in order to account for the deposits so rich in magnetite occurring in Scandinavia and elsewhere, has put forward the theory that the remarkable magnetic properties of the iron-spinellid may account for its segregation, and that the mutual attraction of the magnetite-particles may lead to their accumulation at certain points in the still fluid magma. But this ingenious suggestion omits a very important consideration. It has been shown by Prof. Rücker, that both metallic iron and magnetite, when heated, rapidly lose their magnetic properties, and that at a dull red heat all phenomena both of attraction and polarity disappear alike in metallic iron and in magnetite. Such being the case, it seems impossible to conceive of such a degree of heating of a magma as would permit of internal movements, and yet would not at the same time destroy the attractive properties of the magnetite.

"The other suggested method by which differentiation may be brought about in a magma during the process of crystallization, is based on the fact that, as a general rule, the more basic minerals crystallize out of a molten mass before those of acid composition, and that, as a consequence of this, the matter left liquid continually tends to become more and more acid in composition. That in these masses of molten rock consisting of basic crystals diffused through an acid menstruum, a process of partial or complete liquation may occur, is shown by the phenomena which have been observed at Santorin, Krakatoa, Beinn Hiant, Garabal Hill, etc. This method of differentiation, while it affords a satisfactory mode of explanation of the first class of composite dykes—that so well described by Lawson and Vogt—is clearly inapplicable to the cases in Arran, where the porphyritic crystals and glassy basis in the two constituent rocks are so strikingly contrasted one with another.

"We are thus compelled to fall back upon the view that an actual separation takes place among the materials of a molten magma *before the work of crystallization has commenced;* and I may, in conclusion, pass in review the several suggestions that have been offered to account for such action in a mixed mass of molten silicates.

"Bunsen and many authors since his time have dwelt upon the fact that such molten masses of silicates are really solutions, and must obey all the laws which govern solvent action. Guthrie and Lagorio have especially insisted on this view of the subject.

"Many writers on the question have been impressed by the view that the two magmas into which a mass of molten silicates may be supposed to break up must vary greatly in density; and

several of these writers have suggested, in more or less distinct terms, that this difference in specific gravity may be the efficient cause of their separation. But until recently it was difficult to realize the physical principles that would cause density-differences to come into play as factors of differentiation. The researches of Gouy and Chaperon, however, supply a possible explanation of the phenomenon. These authors have pointed out that, in accordance with well-recognized thermodynamical principles, there should be—in a very great volume of a solution, especially if near saturation—a tendency for concentration to take place in the lower parts of the mass. Such vast masses of molten silicates as must exist in the deeper parts of the earth's crust are precisely the kind of solutions in which we may expect to find the action of this law illustrated.

"There is still another physical principle which has been appealed to as affording an explanation of the differentiation which takes place in a liquefied mass of silicates. In the same year that Gouy and Chaperon demonstrated the causes that would lead to "the concentration of solutions by gravity," van't Hoff published his paper on 'The Role of Osmotic Pressure in the Analogy between Solutions and Gases.' He argued that solutions must follow the law of gaseous tension, and that if two parts of a solution be maintained at different temperatures, concentration must take place in the cooler part. It is interesting to note that, six years before van't Hoff published his general conclusions, Soret had conducted a series of experimental researches which showed that, when two portions of a solution are maintained at different temperatures, there is always a tendency to concentration in the colder part.

"If, as we may assume is generally the case, the lowest portions of the great liquid reservoirs within the earth's crust are at the highest temperature, then the principles established by Gouy and Chaperon and by van't Hoff respectively would operate in contrary directions and tend to neutralize each other. It is sufficient for our present purpose, however, to call attention to the fact that there are now well-recognized physical principles, in accordance with which differentiation must necessarily be set up in the heated solutions constituted by molten masses of mixed silicates, anterior to, and independently of, the liquation that may follow selective crystallization. That differentiation does take place before, as well as during, crystallization, the phenomena exhibited by the two classes of composite dykes afford interesting and striking proofs."

6. *A plumbiferous Tetrahedrite;* by G. Chr. Hoffmann (communicated).—The mineral here described was obtained from the Antelope claim, Kaslo-Slocan mining camp, West Kootanie district, British Columbia. Of the specimens examined—some consisted of the tetrahedrite, in question, associated with galena and small quantities of sphalerite and pyrite; others, of the perfectly pure mineral in a gangue of white opaque quartz. The latter furnished the material employed for the analysis.

It is massive, with an indistinct fibrous structure: color, iron-gray: streak, dark clove-brown: luster, metallic: acquires a beautifully irised tarnish—the colors being various shades of yellow, green, blue, and purple. Mr. R. A. A. Johnston found it to have a specific gravity (after correction for a little intermixed quartz), at 15·5° C., of 5·082. An analysis by him, upon carefully selected material, gave the results of I; and deducting the gangue (silica) and recalculating the remaining constituents for one hundred parts those given in II are obtained.

	S	Sb	As	Cu	Ag	Pb	Zn	Fe	Quartz	
I	20·59	26·81	0·22	21·03	10·64	8·91	5·91	0·88	5·57	= 100·56
II	21·68	28·22	0·23	22·14	11·20	9·38	6·22	0·93		= 100

7. *Minerals and how to study them: A book for beginners in Mineralogy;* by Edward Salisbury Dana. 380 pp. New York, 1895 (John Wiley & Sons).—This is a small work on Mineralogy of very elementary character, the scope of which may be made sufficiently clear by the following quotation from the Preface:—"The author has occupied some hours, which could not be devoted to more serious labor, in preparing this little book, in the hope that it might serve to encourage those who have a desire to learn about minerals, and also to increase the number of those whose tastes may lead them in this direction. He shares with most teachers at the present time, the conviction that the cultivation of the powers of observation is a most essential element in the education of young people of both sexes; he believes further, that no subject is better fitted to accomplish this object and at the same time to excite active interest than that of Mineralogy. The attempt has been made to present the whole subject in a clear, simple and so far as possible, a readable form, without cheapening the science. As the understanding of the different parts of the subject requires some preliminary knowledge of physics and of chemistry, a little elementary matter in these departments has been introduced." . . .

8. *The Constitution of the Silicates;* by F. W. Clarke. Bulletin of the U. S. Geological Survey, No. 125, 109 pp., Washington, 1895.—This bulletin, recently issued, contains a detailed statement of the author's views upon the chemical constitution and structural formulæ of the silicates. Numerous articles by the author upon parts of this subject have from time to time appeared, many of them in this Journal; but all interested will be glad to find here a full presentation of the conclusions to which his study as well as his admirable experimental work have led. While he does not claim that the last word has been said upon this subject, this contribution to the most important and difficult part of mineral chemistry is of very high value and throughout both suggestive and helpful.

9. *Native Silica: a treatise upon a series of specimens of Quartz, Rock crystal, Chalcedony, Agates and Jaspers,* etc.; with a descriptive catalogue of the specimens forming the collection of the late Right Hon. the Earl of Derby, K. G., by Bryce Wright, F.R.G.S. 263 pp. 8vo. London, 1894 (Wyman & Sons).—This is a handsomely printed catalogue containing, besides the

mention of individual specimens, brief but interesting chapters upon the different kinds of precious stones included; we note one on the agate, another on the cutting, polishing and staining of agates at Oberstein, and others similar.

III. Miscellaneous Scientific Intelligence.

1. *Report of the Committee appointed by the Smithsonian Institution to Award the Hogdkins Fund Prizes.*—The Committee of Award for the Hodgkins prizes of the Smithsonian Institution has completed its examination of the two hundred and eighteen papers submitted in competition by contestants.

The committee is composed of the following members: Doctor S. P. Langley, chairman, *ex-officio*, Doctor G. Brown Goode, appointed by the Secretary of the Smithsonian Institution, Assistant Surgeon-General John S. Billings, by the President of the National Academy of Science, Professor M. W. Harrington, by the President of the American Association for the Advancement of Science. The Foreign Advisory Committee, as first constituted, was represented by Monsieur J. Janssen, Professor T. H. Huxley, and Professor von Helmholtz; and after the recent loss of the latter, Doctor W. von Bezold was added. After consultation with these eminent men, the committee decided as follows:

First prize, of ten thousand dollars, for a treatise embodying some new and important discoveries in regard to the nature or properties of atmospheric air, to Lord Rayleigh, of London, and Professor William Ramsay, of the University College, London, for the discovery of *argon*, a new element of the atmosphere.

The *second prize*, of two thousand dollars, is not awarded, owing to the failure of any contestant to comply strictly with the terms of the offer.

The *third prize*, of one thousand dollars, to Doctor Henry de Varigny, of Paris, for the best popular treatise upon atmospheric air, its properties and relationships. Doctor de Varigny's essay is entitled "L'Air et la Vie."

(Signed), S. P. Langley, G. Brown Goode, John S. Billings, M. W. Harrington. August 9, 1895.

Supplementary Report of the Committee appointed by the Smithsonian Institution to Award the Hodgkins Fund Prizes.—After having performed the function to which the committee was called, as announced by the circular of the secretary of the Smithsonian Institution, dated March 31, 1893, which function did not include the award of any medals, there remained several papers to which the committee had been unable to give any prize and to which they had felt desirous to give some honorable mention, and on their representing this to the Smithsonian Institution they have been commissioned to do so, and also to give certain medals of silver and bronze which had been subsequently placed at their disposition.

The committee has decided that honorable mention should be made of the papers, twenty-one in number, included in the following list, which also gives the full names, titles, and addresses

of the authors, and the mottoes or pseudonyms which in four instances were employed. To three of the papers a silver medal is awarded and to six a bronze medal:

Honorable Mention with Silver Medal.

PROF. A. L. HERRERA and DOCTOR VERGARA LOPE, of the City of Mexico: "La Atmosfera de las altitudes y el bienstar del hombre."

MR. C. L. MADSDEN—"Geo"—Helsigör, near Copenhagen, Denmark: Thermographical Studies.

MR. F. A. R. RUSSELL, of London, Vice-President of the Royal Meteorological Society of Great Britain: "The Atmosphere in Relation to Human Life and Health."

Honorable Mention with Bronze Medal.

M. E. DEBURAUX-DEX and M. MAURICE DIBOS—"Spes"—of Rouen, France: "Etudes des courents aériens continentaux et de leur utilization par des ærostats long-courriers."

DOCTOR O. JESSE, of Berlin: "Die leuchtenden Nachtwolken."

DOCTOR A. LOEWY, of Berlin: "Untersuchungen über die Respiration und Cirkulation unter verdünnter und verdichteter Sauerstoffarmer und sauerstoffreicher Luft."

MR. ALEXANDER MCADIE—"Dalgetty"—of Washington: "The known properties of atmospheric air considered in their relationships to research in every department of natural science, and the importance of a study of the atmosphere considered in view of these relationships; the proper direction of future research in connection with the imperfections of atmospheric air and the conditions of that knowledge with other sciences."

MR. HIRAM S. MAXIM, of Kent, England: "Natural and Artificial Flight."

DOCTOR FRANZ OPPENHEIMER and DOCTOR CARL OPPENHEIMER—"E pur si muove"—of Berlin, Germany: "Ueber atmosphärische Luft, ihre Eigenschaften und ihren Zusammenhang mit dem menschlichen Leben."

Honorable Mention.

MR. E. C. C. DALY, of University College, London: "The decomposition of the two constituents of the atmosphere by means of the passage of the electric spark."

PROFESSOR F. H. BIGELOW, of Washington: "Solar and Terrestial Magnetism and their Relation to Meteorology."

DOCTOR J. B. COHEN, of Yorkshire College, Leeds, England: "The Air of Towns."

DOCTOR F. J. B. CORDEIRO, U. S. N., of Washington: "Hypsometry."

PROFESSOR EMILE DUCLAUX, of the French Institute, Paris, France: "Sur l'actinométrie atmosphérique et sur la constitution actinique de l'atmosphère."

PROFESSOR DOCTOR GIESELER, of Bonn, Germany: "Mittlere Tagestemperaturen von Bonn, 1848–88."

DOCTOR LUDWIG ILOSVAY VON NAGY ILOSVA, Professor in the Royal Joseph Polytechnic School, Budapest, Hungary: "Ueber den unmittelbar oxydirenden Bestandtheil der Luft."

DOCTOR A. MAGELASEN, of Christiania, Norway: "Ueber den Zusammenhang und die Verwandschaft der biologischen, meteorlogischen und kosmischen Erscheinungen."

DOCTOR A. MARCUSE, of the Royal Observatory, Berlin, Germany: "Die atmosphärische Luft."

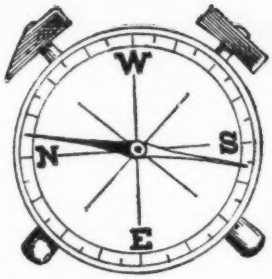
PROFESSOR C. NEES, of the Polytechnic School, Copenhagen, Denmark: "The use of kites and chained air-balloons for observing the velocity of winds, etc."

SURGEON CHARLES SMART, U. S. A., Washington: "An Essay on the Properties, Constitution and Impurities of Atmospheric Air, in Relation to the Promotion of Health and Longevity."

DOCTOR F. VIAULT, of the Faculty of Medicine, Bordeaux, France: "Découverte d'une nouvelle et importante propriété physiologique de l'Air atmosphérique (action hématogène de l'air raréfié)."

(Signed) S. P. Langley, G. Brown Goode, John S. Billings, M. W. Harrington. August 9, 1895.

MINERALS.



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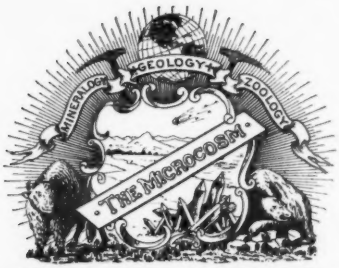

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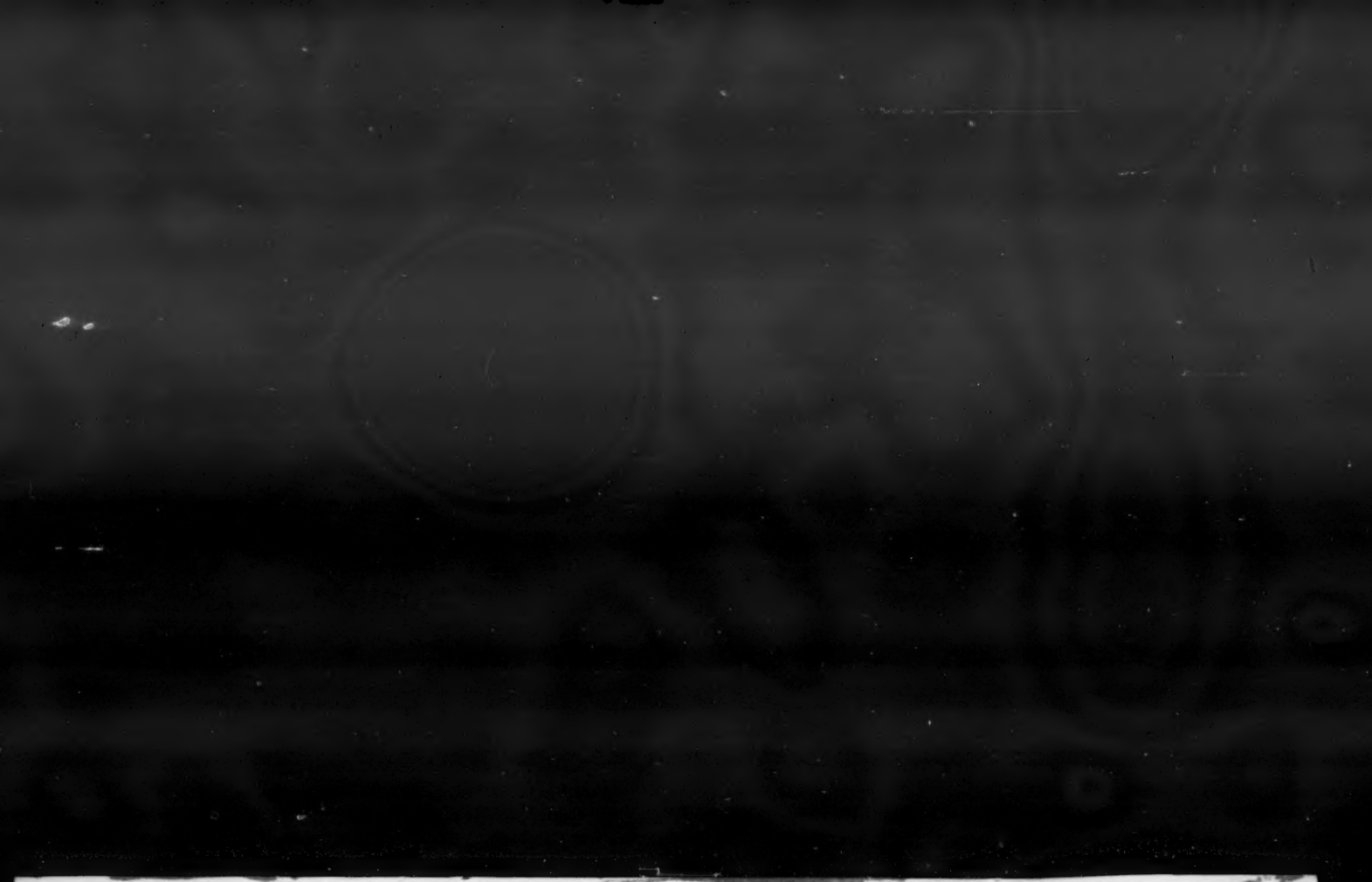

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